BC Hydro Conservation Potential Review 2002

Commercial Sector Report
(Base Year: Fiscal 2000/01)

Electricity Conservation Potential in BC Hydro's Service Area

May 2003

DOC
BC
B685
D:C667P6
2003
COM
c.3

A03-253

BC hydro

This is one of four reports developed for BC Hydro:

- **BC Hydro Conservation Potential Review 2002, Summary Report.**
  Prepared by Polestar Communications Inc.
- **BC Hydro Conservation Potential Review 2002, Residential Sector Report.**
  Prepared by Marbek Resource Consultants and The Sheltair Group Inc.
- **BC Hydro Conservation Potential Review 2002, Commercial Sector Report.**
  Prepared by Marbek Resource Consultants
- **BC Hydro Conservation Potential Review 2002, Industrial Sector Report.**
  Prepared by Marbek Resource Consultants and Willis Energy Services Ltd.

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BC Hydro
Conservation Potential Review 2002

Commercial Sector Report
(Base Year: Fiscal 2000/01)

Submitted to:
BC Hydro

Prepared by:
Marbek Resource Consultants

June 2003

ACKNOWLEDGEMENTS

Completion of the Conservation Potential Review 2002 on an accelerated time table is due in no small part to the consistent input from many BC Hydro staff members, as well as the hard work of the consultants engaged by BC Hydro.

Conservation Potential Review Core Group

The heaviest load fell on the Conservation Potential Review Core Group, which oversaw the management of the effort. The Group consisted of the following members:

- Murray Bond—Quality Assurance Implementation, Power Smart Quality Assurance
- Dorell Carlson—Senior Resource Planning Specialist, Energy Planning
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- Dennis Nelson—Manager, Business Systems Group
- John Oliver—Load Forecast Policy Analyst, Market Forecast
- Paul Robillard—Lead Consultant, Marbek Resource Consultants, Ltd., Ottawa
- Nancy Cooley—CPR Coordinator for BC Hydro, Nancy J. Cooley & Associates, Victoria.

Other BC Hydro Staff

Many others reviewed draft reports and participated in periodic meetings and conference calls. These individuals included the following BC Hydro staff (all are from Power Smart, unless otherwise identified):

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External Review Panel

A number of organizations in BC also agreed to serve on an External Review Panel. They reviewed and commented on draft reports. However, their participation on the Panel should not be construed as indicating agreement with, or endorsement of, any of the CPR 2002 reports. Members of the Panel include:

- Canadian Home Builders' Association of B.C.
- B.C. Public Interest Advocacy Centre—Michael Doherty & Dick Gathercole
- Building Owners' and Managers' Association—Paul LaBranche
- Joint Industry Electric Steering Committee—Lorne Grasley, Dal Scott, Lisa Doig and Dan Potts
- Kootenay–Okanagan Electric Consumers' Association—Fred Marsh
- Pembina Institute for Appropriate Development—Roger Peters
- Sierra Club of B.C.—Tom Hackney, Bo Martin, and Michael Mascall
- David Suzuki Foundation—Dermot Foley
- Union of B.C. Indian Chiefs—David Hunt and Don Bain.

Consultants

The Conservation Potential Review 2002 was undertaken by a team of consultants headed by Marbek Resource Consultants, Ltd. of Ottawa, Ontario. The Commercial Sector Team members included:

- Giuliano Todesco—Marbek Resource Consultants
- Brian O'Donnel and Brian Sikorski—Prism Engineering
- Curt Hepting—Enersys Analytics
- Dr. Edward Vine—Lawrence Berkeley National Laboratory

Nancy J. Cooley (of Nancy J. Cooley & Associates: Embracing Change Creatively, Inc. of Victoria. B.C.) coordinated the Conservation Potential Review effort and provided day-to-day management, the contact point and interface for all participants.

EXECUTIVE SUMMARY

❑ Background and Objectives

In 1991, BC Hydro launched the first collaborative study to estimate the potential for electricity conservation in a Canadian utility. The result was an in-depth analysis of where, how and at what cost electricity consumption in British Columbia (B.C.) could be reduced through electrical efficiency and behavioural changes. A decade later, continued provincial load growth as well as increasing environmental concerns had led to renewed interest in electrical efficiency and, in light of that interest, a decision was made to update the original Conservation Potential Review (CPR) in support of a new set of Power Smart initiatives. This study has been designed with a very tight time frame in order to meet Power Smart planning requirements.

The study had the following objectives:

- To provide BC Hydro's Power Smart program planners with an updated assessment of the remaining electrical efficiency potential[1] in B.C. as a basis for designing new initiatives.
- To estimate the potential contribution of possible Power Smart efficiency programs to the reduction of BC Hydro's peak capacity requirements.
- To identify additional technologies that could become available to provide further savings over the study period.

❑ Scope

It was originally envisioned that the entire scope of this study would directly follow the structure and approach of the original CPR. However, the context has altered significantly in the 10 years since the original CPR: electricity markets throughout North America have changed radically as a result of moves towards deregulation and privatization; better energy-use data for buildings, equipment and industrial processes are available; computer modelling tools for simulating energy use are more sophisticated; and, perhaps most importantly, North American utilities have an additional 10 years' experience in the design, promotion and implementation of DSM programs to draw upon. Consequently, with limited resources of time and money, it was decided to focus on those areas that would best assist BC Hydro's Power Smart planners with the planning and design of new Power Smart initiatives and rates. The intent was also to ensure that the results of this study have a good "shelf life" for Power Smart program and resource planning purposes.

Sector Coverage: This study addresses three sectors: Commercial/Institutional,[2] which is covered in the present report, and Residential and Industrial, which are addressed in separate documents. Within the commercial sector, it was agreed that large buildings would be emphasized, as they represent a particularly attractive potential Power Smart market. Street lighting is not included because this assessment can be easily done from BC Hydro billing statistics.

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[1] The focus was on "hard-wired" electrical efficiency measures; these types of measures are not dependant on repeated customer behaviour to be effective. From a utility's perspective they provide reliable and persistent savings.

[2] Throughout this report, use of the word "commercial" includes both commercial and institutional buildings unless otherwise noted.

Geographical Coverage: The study results are presented for the total BC Hydro service area, excluding the (former) West Kootenay Power service region.[3] This study also provides the results for three regions (Lower Mainland, Vancouver Island and the Interior).

Study Period: This study covers a 15-year period. The base year is the fiscal year (FY) 2000/01, with milestone periods at 5-year increments: 2005/06, 2010/11 and 2015/16. The base year of fiscal year 2000/01[4] was selected as this was the most recent 12-month period for which complete customer data were available.

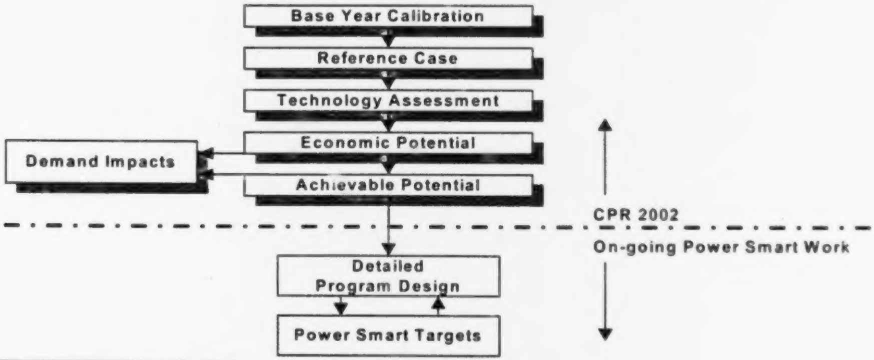
Technologies: This study addresses all electrical efficiency technologies or measures that are expected to be commercially available by the year 2005. Other technologies that control or shift electricity demand or that represent alternative sources of supply are outside of the scope of this study. The use of direct load control technologies or thermal storage provide examples of the former group of excluded technologies while fuel switching to natural gas or solar and district cooling using sea water provide examples of the latter group.

❑ Approach

The detailed end-use analysis of electrical efficiency opportunities in the commercial sector was conducted using two linked modelling platforms, specifically: CEEAM (Commercial Energy and Emissions Analysis Model), a building energy use simulation model; and CSEEM (Commercial Sector Energy End-use Model), a spreadsheet-based macro model. These are Marbek in-house models.

The major steps involved in the analysis are shown in Exhibit E1 and are discussed in the following paragraphs. As illustrated, the results of this CPR study, and in particular the estimation of Achievable Potential, support on-going Power Smart work; however, it should be emphasized that the estimation of Achievable Potential is not synonymous with either the setting of specific Power Smart targets or with program design.

Exhibit E1: Study Approach—Major Analytical Steps



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[3] Areas that are not integrated into BC Hydro's grid are not included.
[4] BC Hydro's fiscal year runs from April 1 to March 31.

Major Analytic Steps and Definitions

This study employs numerous terms that are unique to analyses such as this one; below is a brief description of some of the most important terms. (Others are provided in the Glossary.)

Base Year Calibration	The Base Year is the starting point for the analysis. It provides a detailed description of "where" and "how" energy is currently used in the existing commercial sector building stock. Building energy use simulations were undertaken for each of 15 large and medium building segments and calibrated to actual BC Hydro customer billing data. Small commercial and the "Other" category were derived from the results of the modelled segments.
Reference Case (includes Natural Conservation)	The Reference Case estimates the expected level of electricity consumption that would occur over the study period in the absence of new (post 2000/01) Power Smart initiatives. It provides the point of comparison for the subsequent calculation of "economic" and "achievable" electricity savings potentials. Creation of the Reference Case required the development of detailed profiles for new buildings in each of the building segments, estimation of the expected growth in building stock, and, finally an estimation of "natural" changes affecting electricity consumption over the study period. The Reference Case aligns well with BC Hydro's December 2000 Load Forecast, which also incorporates "natural conservation" but no new Power Smart initiatives.
Technology Assessment	Energy efficiency upgrade options were identified that met the criteria, as outlined above in the study's scope. Technology cost and performance data were compiled relative to the base line technology and the Cost of Conserved Energy (CCE) was calculated for each upgrade option. The CCE is the annualized incremental capital and O&M cost of the upgrade measure divided by the annual energy savings achieved.
Economic Potential Forecast	The Economic Potential Forecast is the level of electricity consumption that would occur if all equipment and building envelopes were upgraded to the level that is cost-effective, from BC Hydro's perspective using life-cycle costing, against the long-run avoided cost of electricity in the BC Hydro service region, which in this study was set at $0.06/kWh. All the energy efficiency upgrades included in the technology assessment that had a CCE[5] equal to, or less than, the avoided cost of new electricity supply ($0.06/kWh) were incorporated into the Economic Potential Forecast.

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[5] The CCE is defined in Section 4 (4.1.1).

Achievable Potential

The Achievable Potential is the proportion of the savings identified in the Economic Potential Forecast that could realistically be achieved within the study period. Achievable Potential recognizes that it is difficult to induce customers to purchase and install all the energy-efficient technologies that meet the criteria defined by the Economic Potential Forecast. The results are presented as a range, defined as "Most Likely" and " Upper".[6]

Estimates provided were developed in collaboration with Power Smart program personnel; they are based on a combination of empirical results from earlier Power Smart initiatives, results in other jurisdictions and a qualitative assessment of current market and customer receptivity to investments in energy efficiency. The range of estimates also recognize that in addition to factors within BC Hydro's control (e.g., program design), factors external to the utility (e.g., state of economy, Kyoto implications etc.) can significantly influence the Achievable Potential.

Demand Impacts

A methodology was developed to derive the on-peak demand impacts from the electricity consumption values contained in the Potential estimates noted above. In each case, the demand impacts report the reduction in BC Hydro's on-peak system generation requirements that would result from implementation of the energy-efficient measures included in each Potential estimate. For this study, BC Hydro's on-peak period was defined as weekdays from 6 a.m. to 10 p.m. during the months of December and January.

❑ Results and Findings

A summary of the levels of annual electricity consumption contained in each of the preceding forecasts, by milestone year, is presented in Exhibits E2 and E3, and discussed briefly in the paragraphs below.

Exhibit E2
Summary of Forecast Results—Annual Electricity Consumption
Commercial Sector, (GWh/yr.)*

Annual Consumption (GWh/yr.) Commercial Sector						Potential Annual Savings (GWh/yr.)		
Milestone Year	Base Year	Reference Case	Economic	Achievable		Economic	Achievable	
				Likely	Upper		Likely	Upper
2000/01	12,739	12,739						
2005/06		14,314	12,155	14,124	13,918	2,159	191	396
2010/11		16,185	13,431	15,600	15,170	2,754	585	1,015
2015/16		18,056	14,984	16,928	16,437	3,072	1,128	1,619

*Results are measured at the customer's point of use and do not include line losses.

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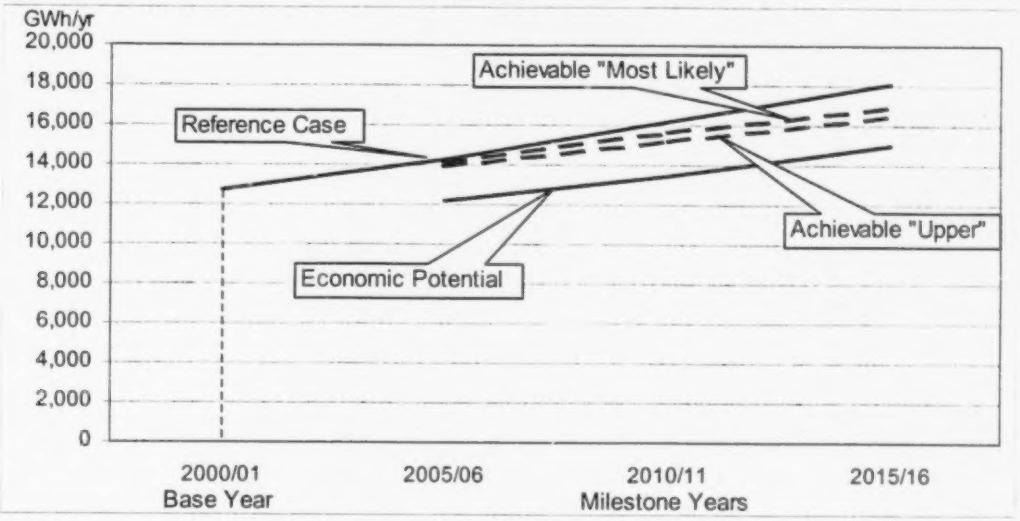
[6] Definitions of the Achievable scenarios are provided in Section 6.2.

Exhibit E3
Graphic of Forecast Results—Annual Electricity Consumption Commercial Sector, (GWh/yr.)



Base Year Electricity Use and Calibration

In the base year of 2000/01, BC Hydro's commercial sector consumed 12,737 GWh. Exhibit E4 shows that lighting is the major end use and accounts for 49% of the total commercial sector electricity use. Heating Ventilation and Air-Conditioning Equipment (HVAC) is the second largest end use, accounting for 17% of total electricity use, followed by office equipment and plug loads (10%).

Exhibit E4: Commercial Sector Base Year Electricitv Use Bv End-use

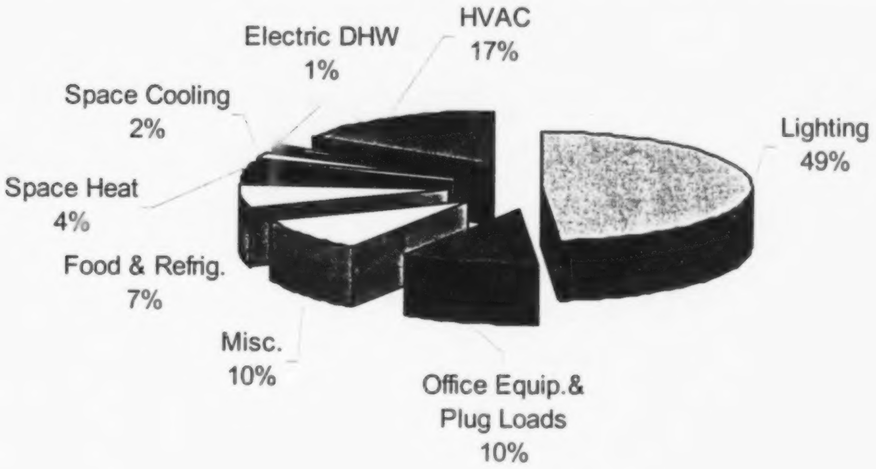
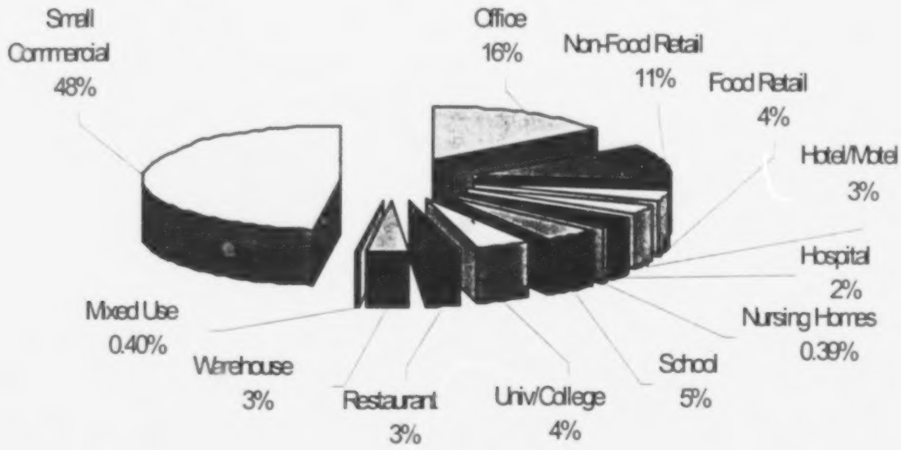


Exhibit E5 shows the distribution of base year electricity consumption by building segment. As illustrated, the office and non-food retail building segments account for the largest share of electricity use among the modelled building segments. The small commercial segment, which consists of the many small customers within each of the modelled building segments (e.g., office, hospital etc.), accounts for 49 % of the commercial base year electricity use.

Exhibit E5: Commercial Sector Base Year Electricity Use By Building Segment



Reference Case

In the absence of new Power Smart initiatives, the study estimates that electricity consumption in the Commercial Sector will grow to 14,314 GWh/yr. by 2005/06, to 16,185 GWh/yr. by 2010/11 and 18,056 GWh/yr. by 2015/16. This represents an overall growth of about 42% in the period and compares very closely with BC Hydro's own December 2000 forecast which also includes consideration of the impacts of "natural conservation". Natural conservation is expected to have most impact on three end uses: lighting, space cooling and plug loads. As a result of natural conservation in existing buildings, it is expected that approximately 50% of the remaining (T12) inefficient fluorescent lighting will be converted to more-efficient (T8) fluorescent lamps with electronic ballasts. Similarly, it is assumed that the ozone-depleting substance regulations will continue to drive cooling equipment replacements and that new cooling equipment will provide improved energy performance. New building performance is improved over the period with the increased incorporation of integrated design concepts. In contrast, office equipment plug loads in both existing and new buildings are expected to grow as a result of changes such as, increased density of computer use per occupant, increased use of network computers and servers and growth in other peripherals, such as telephone network equipment.

Economic Potential Forecast

Under the conditions of the Economic Potential Forecast, the study estimated that electricity consumption in the Commercial Sector would grow to 14,984 GWh by FY 2015/16. Annual savings relative to the Reference Case are 3,072 GWh/yr. or about 17%. The Economic Potential annual savings in the remaining milestone years are 2,754 GWh/yr. in 2010/11 and 2,159 GWh/yr. in 2005/06.

Achievable Potential

The electricity savings opportunities identified in the Economic Potential Forecast were "bundled", by end use, into a set of "Actions" reflecting a way in which initiatives may be undertaken. A brief profile was developed for each of the identified Actions. The Action Profiles provided a "high-level" logic framework that guided participant discussions in a full-day workshop as well as follow up meetings involving the consultant team and Power Smart personnel. The results are presented in Exhibit E6 by Action and by milestone year.

Consistent with the results in the Economic Potential Forecast, the most significant Achievable Savings opportunities were in the Actions that addressed lighting, small commercial building retrofit and design, high-performance new buildings and HVAC.

Exhibit E6: Summary of Achievable Savings for BC Hydro Service Area, by Action and Milestone Year

Service Region / Action	Annual Electricity Savings (GWh/yr.), by Milestone Year					
	2005/06		2010/11		2015/16	
	Most Likely	Upper	Most Likely	Upper	Most Likely	Upper
C1 - Lighting	95.8	174.3	283.3	426.4	510.5	634.2
C2 - HVAC Retrofit	4.5	10.3	20.6	53.4	54.0	92.4
C3 - Heating and Cooling Retrofit	1.0	2.1	4.2	10.5	8.5	19.0
C4 - High Perf. Large Com. Buildings	14.6	31.1	58.9	110.5	129.9	245.1
C5 - Small Commercial Retrofit and Design	41.4	111.5	134.3	249.0	264.1	372.9
C6 - Energy Star Computers and Electronic Equipment	3.8	7.5	22.5	45.0	37.5	67.5
C7 - Commercial Refrigeration Retrofit	1.6	3.2	5.7	8.9	11.6	20.8
C8 - Other Commercial Buildings	15.0	30.0	30.0	60.0	60.0	90.0
C9 - Non-buildings	12.9	25.8	25.8	51.6	51.6	77.4
Total BC Hydro	**190.5**	**395.8**	**585.4**	**1015.2**	**1127.7**	**1619.3**

*Results are measured at the customer's point of use and do not include line losses.

Demand Impacts of Electrical Efficiency Measures

This study provided the first attempt by BC Hydro to estimate the demand impacts associated with the electrical efficiency measures incorporated in each of the preceding forecasts. As noted previously, this study did not focus *per se* on demand reduction, and the technology and load control strategies that would reduce peak capacity requirements lie beyond the scope of the present work. However, as illustrated in Exhibit E7, electricity savings contained in each of the forecasts have significant on-peak demand implications.

Relative to the Reference Case, on-peak demand savings in the Economic Potential Forecast are 314 MW in FY 2005/06, rising to 408 MW and 450 MW in FYs 2010/11 and 2015/16, respectively. Achievable Potential on-peak demand savings in FY 2005/06 range from 29 MW (Most Likely) to 60 MW (Upper), depending on scenario. By FY 2015/16 Achievable Potential on-peak demand savings range from 172 MW (Most Likely) to 247 MW (Upper), again depending on scenario.

Exhibit E7: On-Peak Demand Savings Commercial Sector

Average On-peak Demand Commercial Sector (MW)						Potential On-peak Demand Savings (MW)		
Milestone Year	Base Year	Reference Case	Economic	Achievable		Economic	Achievable	
				Likely	Upper		Likely	Upper
2000/01	1,961	1,961						
2005/06		2,180	1,866	2,151	2,120	314	29	60
2010/11		2,438	2,030	2,350	2,285	408	88	153
2015/16		2,699	2,248	2,527	2,452	450	172	247

❑ Summary of Findings

The study findings confirm the existence of significant potential cost-effective electrical efficiency improvements in B.C.'s commercial sector. In the "most likely" and "upper" achievable scenarios those electrical efficiency improvements would provide between 1,100 and 1,600 GWh/yr. of electricity savings by FY 2015/16, as well as on-peak demand savings of approximately 170 to 250 MW.

Within the priority large building segments that were subject to detailed modelling, savings potential is particularly significant in the office and retail segments, followed by schools and universities/colleges. Lighting, more efficient HVAC systems and new high-performance buildings account for nearly 60% of the identified Achievable Savings potential. Potential savings in the small commercial building segment are also large.

Note: As in any study of this type, the results presented in this report are based on a number of important assumptions. Assumptions such as those related to the current penetration of efficient technologies and the rate of future growth in the stock of commercial buildings are particularly influential. Wherever possible, the assumptions used in this study are consistent with those used by BC Hydro. However, the reader is referred to a number of caveats throughout the main text of the report.

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1. INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

In 1991, BC Hydro launched the first collaborative utility process to estimate the potential for electricity conservation in a Canadian utility. A collaborative committee of electricity stakeholders oversaw the research, and the report presented an in-depth analysis of where, how and at what cost electricity demand in British Columbia (B.C.) could be reduced through efficiency and behavioral changes.

A decade later, new pressures and structures in the industry are leading to renewed interest in conservation and load management. Increasing peak demands are encouraging consideration of demand-side management (DSM) as a means to defer transmission investment in certain areas. At the same time, BC Hydro's natural-gas-based generation plan identifies risks related to increased greenhouse gas emissions, risks that electrical efficiency can mitigate. There is also renewed interest in neighbouring jurisdictions in conservation as a means to mitigate the risk of price spikes and shortages in competitive markets. Since the original Conservation Potential Review (CPR), the performance efficiency of major energy-using technologies has continued to improve, new products have become available in the market and additional technologies, based largely on advances in Information Technology (IT) and materials science, are under development: these will offer further improvement.

Given the above conditions, BC Hydro initiated the current study with the following objectives:

- To provide BC Hydro's Power Smart program planners with an updated assessment of the remaining "hard-wired" electrical efficiency[7] potential within B.C., an assessment that will assist them in the design and implementation of a new set of Power Smart initiatives.
- To estimate the potential contribution of possible Power Smart electrical efficiency programs to the reduction of BC Hydro's peak demand requirements.
- To identify additional technologies that could become available to provide further savings over the study period.

1.2 STUDY SCOPE

It was originally envisioned that the entire scope of this study would directly follow the structure and approach of the original CPR. However, the context has altered significantly in the 10 years since the original CPR: electricity markets throughout North America have changed radically as a result of moves towards deregulation and privatization; better energy-use data for buildings, equipment and industrial processes are available; computer modelling tools for simulating electricity use are more sophisticated; and, perhaps most importantly, North American utilities have an additional 10 years' experience in the design, promotion and implementation of DSM programs to draw upon. Consequently, with limited resources of time and money, it was decided

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[7] The focus was on "hard-wired" electrical efficiency measures; these types of measures are not dependant on repeated customer behaviour to be effective. From a utility's perspective they provide reliable and persistent savings.

to focus on those areas that would best assist BC Hydro's Power Smart program planners with the design of new Power Smart initiatives. The intent was also to ensure that the results of this study have a good "shelf life" for Power Smart program and resource planning purposes.
The most significant changes to the original CPR scope that were introduced in this study are:

- **Focus is on economic potential.** The original CPR included estimates of unconstrained technical and social potential[8] for electricity savings. While these potentials provided useful reference points at the time, the experience of the last 10 years has emphasized the importance of the economical potential[9] as the basis for utility program planning.

  The estimated potentials from the original CPR were intended to establish what the outside limits of conservation might be if one could get 100% of all the technological changes available and projected at the time and if one could get all customers to behave in the most energy conserving manner. When BC Hydro decided to update its estimates, it was more interested in how much of the remaining potential could be realistically achieved through renewed investment in DSM rather than what could be achieved through customers changing their behaviour. Consequently, this CPR focuses on economic potential and primarily on so called "hard-wired" options (those that are little or not at all affected by customer behavior). The resulting potential estimates should, therefore, be read as a reasonable estimate of what BC Hydro could target with new Power Smart programs. Unlike the original CPR estimates, it cannot be read as an estimate of what the potential pool of conserved electrical energy could be. Clearly, the latter is much larger than this CPR would indicate, since it would contain the effects of: changes in customer attitude and behaviour; changes in electricity rate structures; and changes in provincial and/or federal government policies and programs with respect to electricity.

- **Electricity savings are calculated relative to a Reference Case that includes natural conservation.** The original CPR calculated electricity savings on the basis of a frozen efficiency forecast (i.e., "no efficiency improvements"). However, this frozen efficiency forecast is not as relevant today, as electrical efficiency improvements have gained a momentum of their own and continue to be promoted by a variety of public- and private-sector proponents.

- **The demand impacts of the electrical efficiency measures are estimated.** Demand was not addressed in the original CPR; however, demand constraints have become a more important concern to BC Hydro than at the time of the original CPR. Consequently, this CPR includes an estimate of the demand reductions that would occur as a result of the electrical efficiency savings contained in the study (Note: specific load control or load shifting measures are not included within the study scope).

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[8] The social potential that was included in the original CPR included attitude and behavioural changes such as turning off lights.

[9] The original CPR also attempted to quantify *all* technologies that were expected to become "economic" by the end of the study period. The current CPR set the first milestone year of 2005 as the economic cut-off date for quantitative inclusion of technologies in the economic potential forecast. This study does identify additional technologies that may become economic between 2005 and the end of the study period, but does not attempt to quantify their potential savings contribution.

With the exception of the above changes, the scope of this CPR remains largely unchanged from the 1991 study. More specifically:

- **Sector Coverage:** This study addresses the same three sectors: Commercial and Institutional,[10] which is covered in the present report, and Residential and Industrial, which are addressed in two separate documents. Within the commercial sector, it was agreed that large buildings would be emphasized, as they represent a particularly attractive potential Power Smart market. As in the original CPR, street lighting is not included.

- **Geographical Coverage**: The study results are presented for the total BC Hydro service area but exclude, as in the original CPR, the (former) West Kootenay Power service region. In contrast to the original CPR, this study also provides the results for three regions (Lower Mainland, Vancouver Island and the Interior). [11]

- **Study Period**: This study also covers a 15-year period. The base year is the fiscal year (FY) 2000/01, with milestone periods at 5-year increments: 2005/06, 2010/11 and 2015/16. The base year of fiscal year 2000/01 was selected, as this was the most recent 12-month period for which complete customer data were available.

- **Technologies:** This study addresses all electrical efficiency technologies or measures that are expected to be commercially available by the year 2005. A summary of the technologies included in this study is provided in Exhibit 1.1.

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[10] Throughout this report, use of the word "commercial" includes both commercial and institutional buildings unless otherwise noted.

[11] ***Lower Mainland*** includes the Lower Mainland of B.C., the Fraser Valley as far east as Hope, the Sunshine Coast and Powell River. ***Vancouver Island*** includes all of Vancouver Island plus those Gulf Islands that get their electricity supply from Vancouver Island. ***Interior*** includes the remainder of BC Hydro's service area. Areas that are not integrated into BC Hydro's grid are not included.

Exhibit 1.1: Commercial Sector Technologies Included in Study

End Use	Efficient Technologies	Core Analysis	Additional Technologies *(see Section 8)*
Lighting	Next Generation T8	X	
	High-efficiency Metal-halide	X	
	Reduced lighting power densities	X	
	Pulse-start Metal-halide	X	
	Compact Fluorescent Lamps (CFLs)	X	
	White LED incl exit lighting	X	
	Tungsten-matrix Filament for Incandescents	X	
	High-output T5 Fluorescent Lamps	X	
	Advanced Full Integrated Lighting Controls (Ergolight)	X	
	Universal Dimming Switch	X	
	Two Photon Lighting		X
	Daylighting Enhancement	X	
Building Envelope	Gas-filled Insulation Panels	X	
	Vacuum Insulation Panels	X	
	Phase Change Wallboard	X	
	Aerogel Glazings		X
	High-performance Glazings	X	
Heating/Cooling	Displacement Ventilation	X	
	Cold-climate Heat Pumps	X	
	Advanced Heat Pump Controls	X	
	Variable Speed Fans	X	
	Variable Speed Pumps	X	
	Low-temperature Distribution Fans	X	
	2nd Generation Building Automation Systems (BAS)	X	
	Chiller/Cooler upgrade	X	
	Recommissioning	X	
	Energy-efficient Motors	X	
	Magnetic Refrigeration		X
Service Hot Water	Efficient Shower/Faucet	X	
	Auto Shut Off	X	
Refrigeration	Thermo-acoustic Refrigeration		X
	Linear Compressors (for refrigerators)		X
	Magnetic Refrigeration		X
	Doors and Covers	X	
	Integrated Compressors	X	
	Unequal demand multi-plex compressors	X	
	Hot Gas Defrost	X	
	Liquid Pressure Amplification	X	
Plug In Equipment	Reduced Standby for Computers	X	
Building Design	Integrated Design to 25% below current practice	X	
	Integrated Design to 40% below current practice	X	

As in the original CPR, other technologies that control or shift electricity demand or represent alternative sources of electricity supply are outside of the scope of this study. The use of advanced two-way thermostats and thermal energy storage provide examples of the former group of excluded technologies, while fuel switching to natural gas or solar and district cooling using sea water provide examples of the latter group.

Exhibit 1.1 also shows whether selected technologies are addressed in the "core" analysis or if they are an emerging technology. The "core" technologies are incorporated in the main analysis. The technologies noted in the "additional" column of Exhibit 1.1 have not yet reached the point of full commercialization; nonetheless, it is recognized that they could become commercially available in the period. These latter technologies are addressed separately in Section 8 and their potential contribution to further electricity savings over the study period is briefly noted.

1.3 DEFINITIONS

This study employs numerous terms that are unique to analyses such as this one and consequently it is important to ensure that all readers have a clear understanding of what each term means when applied to this study. Below is a brief description of some of the most important terms. The reader is also referred to the Glossary of Terms, which is found in Section 11 of this report. Key terms include the following:

Base Year Calibration	The Base Year is the starting point for the analysis. It provides a detailed description of "where" and "how" energy is currently used in the existing commercial sector building stock. Building electricity use simulations were undertaken for each of 15 large and medium building segments and calibrated to actual BC Hydro customer billing data. Small commercial and the "Other" category were derived from the results of the modelled segments.
Reference Case (includes Natural Conservation)	The Reference Case estimates the expected level of electricity consumption that would occur over the study period in the absence of new Power Smart initiatives. It provides the point of comparison for the subsequent calculation of "economic" and "achievable" electricity savings potentials. Creation of the Reference Case required the development of detailed profiles for new buildings in each of the building segments, estimation of the expected growth in building stock, and, finally an estimation of "natural" changes affecting electricity consumption over the study period. The Reference Case aligns well with BC Hydro's December 2000 Load Forecast, which also incorporates "natural conservation" but no new Power Smart initiatives.
Technology Assessment	Electrical efficiency upgrade options were identified that met the criteria, as outlined above in the study's scope. Technology cost and performance data were compiled relative to the base line technology and the Cost of Conserved Energy (CCE) was calculated for each upgrade option. The CCE is the annualized incremental capital and O&M cost of the upgrade measure divided by the annual savings achieved.

Economic Potential Forecast	The Economic Potential Forecast is the level of electricity consumption that would occur if all equipment and building envelopes were upgraded to the level that is cost-effective, from BC Hydro's perspective using life-cycle costing, against the long-run avoided cost of electricity in the BC Hydro service region, which in this study was set at $0.06/kWh. All the electrical efficiency upgrades included in the technology assessment that had a CCE equal to, or less than, the avoided cost of new electricity supply ($0.06/kWh) were incorporated into the Economic Potential Forecast.
Achievable Potential	The Achievable Potential is the proportion of the savings identified in the Economic Potential Forecast that could realistically be achieved within the study period. Achievable Potential recognizes that it is practically difficult to induce customers to purchase and install all the electrical efficiency technologies that meet the criteria defined by the Economic Potential Forecast. The results are presented as a range, defined as "Most Likely" and " Upper". Estimates provided were developed in collaboration with Power Smart program personnel; they are based on a combination of empirical results from earlier Power Smart initiatives, results in other jurisdictions and a qualitative assessment of current market and customer receptivity to electrical efficiency investments. The range of estimates also recognize that in addition to factors within BC Hydro's control (e.g., program design), factors external to the utility (e.g., state of economy, Kyoto implications etc.) can significantly influence the Achievable Potential.
Demand Impacts	A methodology was developed to derive the on-peak demand impacts from the electricity consumption values contained in the Potential estimates noted above. In each case, the demand impacts report the reduction in BC Hydro's on-peak system generation requirements that would result from implementation of the electrical efficiency measures included in each Potential estimate. For this study, BC Hydro's on-peak period was defined as weekdays from 6 a.m. to 10 p.m. during the months of December and January.

1.4 OVERVIEW OF APPROACH

To meet the objectives outlined above, the study was conducted within a highly iterative process that involved a number of well defined steps. At the completion of each step, the client[12] reviewed the results and, as applicable, revisions were identified and incorporated into the interim results. The study then progressed to the next step. A summary of the steps is presented below.

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[12] Members of the External Review Panel also read and commented on draft reports, and participated in aspects of the study.

A summary of the steps is presented below.

Step 1: **Develop Base Year Calibration Using Actual BC Hydro Billing Data**

- Compile and analyze available data on B.C.'s existing building stock.
- Develop detailed technical descriptions of the existing building stock.
- Undertake computer simulations of electricity use in each building type and compare these with actual building billing and audit data.
- Compile actual BC Hydro billing data.
- Create sector model inputs and generate results.
- Calibrate sector model results using actual utility billing data.

Step 2: **Develop Reference Case**

- Compile and analyze building design, equipment and operations data and develop detailed technical descriptions of the new building stock.
- Develop computer simulations of electricity use in each new building type.
- Compile data on forecast levels of building stock growth and "natural" changes in equipment efficiency levels and/or practices.
- Define sector model inputs and create forecasts of electricity use for each of the milestone years.
- Compare sector model results with BC Hydro's "basic" forecast for period.

Step 3: **Develop and Assess Energy Efficiency Upgrade Options**

- Develop list of electrical efficiency measures.
- Compile detailed cost and performance data for each measure.
- Identify the baseline technologies employed in the Reference Case.
- Develop energy efficiency upgrade options for each end use.
- Determine the Cost of Conserved Electricity (CCE)[13] for each upgrade option.

Step 4: **Estimate Economic Electricity Savings Potential**

- Compile utility economic data on current and forecast costs for new electricity generation.
- Screen the identified energy efficiency upgrade options from Step 3 against the utility economic data.
- Identify the combinations of energy efficiency upgrade options and building types where the cost of saving a kilowatt of electricity is equal to, or less than, the cost of new electricity generation.
- Apply the economically attractive electrical efficiency measures from Step 3 within the energy use simulation model developed previously for each building type.
- Determine annual electricity consumption in each building type when the economic efficiency measures are employed.
- Compare the electricity consumption levels when all economic efficiency

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[13] The term CCE that is used in this study refers to the same methodology as was used in the original CPR. However, in the original CPR, the term Total Resource Cost (TRC) was used. In both CPRs program and administrative costs were excluded. Since the TRC normally includes program and administrative costs, it was considered clearer to use the term Cost of Conserved Energy in this effort. Adding 0.5 to 1 cent per kilowatt hour to the CCE used in this review would give a rough approximation of the TRC as it is usually calculated. Further detail on the CCE is provided in Section 4 (4.1.1).

measures are used with the Reference Case consumption levels and calculate the electricity savings.

Step 5: **Estimate Achievable Electricity Savings Potential**

- "Bundle" the electricity saving opportunities identified in the Economic Potential Forecast into a set of Actions.
- Create "Action Profiles" for each of the identified Actions that provide a "high-level" rationale and direction, including target technologies and sub-markets as well as key barriers and a broad intervention strategy.
- Review historical achievable program results and prepare preliminary Action Assessment Worksheets.
- Consult with Power Smart personnel, review preliminary estimates and reach general agreement on "most likely" and "upper" range of achievable potential.

Step 6: **Estimate Demand Impacts of Economic and Achievable Electricity Savings Potential**

- Define utility peak periods and estimate the distribution of base year annual electricity use within each period, based on best available load data.
- Compare demand estimates with best available utility system and sector load data.
- Using same approach as for the estimate of base year, calculate average on-peak demand for the Reference Case as well as Economic Potential and Achievable Potential Forecasts.
- Calculate on-peak demand savings for the Economic and Achievable Potential Forecasts relative to the Reference Case.

Step 7: **Review Additional Technologies**

- A brief qualitative write up was prepared for those technologies that did not meet the study criteria for inclusion but could, nonetheless, provide additional savings under the appropriate conditions.

1.5 ANALYTICAL MODELS

The detailed end-use analysis of the commercial sector was conducted using two linked modelling platforms as follows:

- ***CEEAM*** (Commercial Electricity and Emissions Analysis Model), an in-house, simulation model, developed in conjunction with Natural Resources Canada for modelling electricity use in commercial-institutional building stock.
- ***CSEEM*** (Commercial Sector Electricity End-use Model), an in-house spreadsheet based macro model

CEEAM was used to develop commercial electricity end-use intensities (EUIs) for each of the commercial and institutional building archetypes. Developed in conjunction with Natural Resources Canada (NRCan), CEEAM has been successfully employed in numerous recent assignments for NRCan, Consumers Gas and international DSM projects, including the extensive national climate change analysis conducted for the federal Buildings Table. CEEAM is a robust modelling platform and its results have been verified against actual end-use metered data for the cities of Ottawa and Toronto and against DOE-2.1E.

CEEAM has been developed specifically for applications such as this study. One of CEEAM's particular strengths is the capability to simulate electricity performance not only in a given building but also in an entire stock of similar buildings (e.g., all large offices). In particular, it is capable of tracking the penetration of multiple technologies and combinations that are not possible in other simulation software, such as DOE 2.

CEEAM simulates the electricity consumption and peak demand for all electricity end-uses present in a given commercial building segment. CEEAM calculates energy use and emissions by end-use and reports them in $kWh/m^2/yr$. and kg eCO_2/m^2. Because CEEAM is a full modelling program, it calculates both building heating and cooling loads (internal and transmission). It therefore accounts for interactive effects such as the increase in heating electricity use and decrease in cooling electricity use from lighting retrofits. CEEAM also uses equipment part load performance curves to accurately model the seasonal efficiency of heating and cooling plants.

The commercial EUIs derived by CEEAM provide inputs into Marbek's in-house ***C***ommercial ***S***ector ***E***lectricity ***E***nd-use ***M***odel (CSEEM). **CSEEM**, as noted above, is a spreadsheet-based macro model. It consists of two modules:

- A General Parameters module that contains general sector data (e.g., number of dwellings, growth rates, etc.);
- A Building Profile module that contains the EUI data for each of the selected building segments.

CSEEM combines the data from each of the modules and provides total electricity use by Service region, building segment and end use. CSEEM also enables the analyst to estimate the demand impacts of the electrical efficiency measures introduced in the Economic Potential Forecast.

1.6 THIS REPORT

The remainder of this report is organized as follows:

- **Section 2** presents results and the specific tasks involved in developing the base year calibration.
- **Section 3** presents the Commercial Reference Case for the FYs 2000/01 to 2015/16.
- **Section 4** identifies and assesses technical options for improving electrical efficiency within the Commercial Sector.
- **Section 5** presents the Commercial Sector Economic Potential Forecast for the study period (FYs 2000/01 to 2015/16).

- **Section 6** presents the Achievable Potentials, which are an estimate of the proportion of savings identified in the Economic Potential Forecast that can realistically be achieved within the study period.
- **Section 7** estimates the demand impacts of the Economic Potential Forecast.
- **Section 8** provides a qualitative review of selected additional technologies that could provide additional electricity savings over the study period.
- **Section 9** summarizes the key study findings.
- **Section 10** lists sources and references.
- **Section 11** presents a glossary of terms used throughout this study.

2. BASE YEAR CALIBRATION

2.1 INTRODUCTION

This section summarizes the major tasks involved in the development of the Base Year[14] calibration for the Commercial Sector. The discussion is organized into the following subsections:

- Segmentation of Commercial Buildings
- Development of Detailed Profiles for Existing Buildings
- Derivation of Saturation and Fuel Share Data
- Floor Area Calculation
- Summary of Model Results
- Comparison with BC Hydro Billing Data.

2.2 SEGMENTATION OF COMMERCIAL BUILDINGS

The first major task in developing the base year calibration involved the segmentation of the commercial building stock. As in similar analyses, the choice of specific building segments is driven by the need to facilitate the subsequent analysis and modelling of potential electrical efficiency improvements. Therefore, selected building segments need to be reasonably similar in terms of major design and operating considerations, such as building size, mechanical and electrical systems, annual operating hours, etc.

Based on the results of client discussions, the following Commercial Sector building segments were defined:

- Large Office
- Medium Office
- Large Non-food Retail
- Medium Non-food Retail
- Food Retail
- Large Hotel
- Medium Hotel/Motel
- Hospital
- Nursing Home
- Large School
- Medium School
- University/College
- Restaurant/Tavern
- Warehouse/Wholesale
- Mixed Use
- Small Commercial.

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[14] The fiscal year 2000/2001 was selected for the base year, as this is the most recent period for which complete customer data are available. Additionally, the fiscal rather than calendar year was chosen as it was felt that this approach reduced potential data reporting overlap during December/January period when space heating electricity use is typically greatest.

It was also agreed to track "Other Buildings" and "Other Non-Buildings" throughout the study but not to subject them to detailed analysis. Estimates of the potential for electricity savings in "Other Buildings" were developed in consultation with BC Hydro personnel and were based on the savings levels determined in the detailed portion of the analysis.

2.3 DEVELOPMENT OF DETAILED PROFILES FOR EXISTING BUILDINGS

The next major task involved the development of building profiles that contain detailed technical data on building specifications, mechanical equipment, lighting equipment and electricity use in each of the commercial building segments noted above.[15, 16,17]

Development of the detailed building profiles relied on an analysis of existing B.C. commercial building audit data taken from BC Hydro and consultant team files[18], gleaned from discussions with building design practitioners and based on the professional experience of the study team personnel.

Building profiles were created for two weather regions:

- The Lower Mainland and the Vancouver Island service regions (using Vancouver weather data); and
- The Interior service region (using blended weather data from Summerland and Prince George).

Exhibit 2.1 presents a sample Summary Building Profile.

Appendix A (Lower Mainland and Vancouver Island)[19] and Appendix B (Interior) contain detailed building profiles for each building segment and service region.

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[15] Building profiles were also created, using CEEAM, for medium- and high-rise apartments, as well as low-rise apartments; however, as previously agreed, these results are reported within the Residential sector. An abbreviated building profile was created for the restaurant/tavern segment as energy use in this segment is dominated by "plug-in" equipment.

[16] Excludes the small commercial building segment.

[17] There is some uncertainty related to the space cooling loads in schools due to uncertainty related to the amount of floor area that is actually conditioned. Available data provided insight into the number of schools with space cooling but did not provide insight into the percentage of the floor space in those schools that had access to space cooling.

[18] Data inputs were greatly assisted by Vancouver-based study team members, Prism Engineering and Enersys Analytics.

[19] A glossary of terms and a list of abbreviations used in the Building Profiles are presented as sections 11 and 12, respectively.

Exhibit 2.1: Sample Existing Large Office

Summary Building Profile

Building Type: Large Office	**Location:** Lower Mainland
Description: This archetype is based on 58 large office buildings with a combined published "rentable" floor area of 15,600,000 ft²) The buildings range in size from 100,000 to 600,000 ft² constructed between 1910 and 2000. Electrical energy intensities (electrical bepi) ranges from 11 kWh/ft² yr to 34 kWh/ft² yr. The average is 25.5 kWh/ft² yr. This sample represents approximately 70% of the total 18,000,000 ft² of published rentable floor area in the Lower Mainland.	**The Average Building:** The average building characteristics used to define this building profile are as follows: - average building size 230,000 ft² - average footprint 12,100 ft² assumes a 110 ' x 110 ' footprint - 19 stories

Building Specifications:

roof construction	0.7 W/m² °C	0.12 Btu/hr ft² °F
wall construction	0.95 W/m² °C	0.17 Btu/hr ft² °F
windows	5.7 W/m² °C	1.00 Btu/hr ft² °F
shading coefficient	0.66	
window to wall ratio	0.4	

General Lighting & LPD

660 Lux	18.8 W/m²
61 ft-candles	1.7 W/ft²

System Types

INC	CFL	T12ES	T8Magnetc	T8Electron	Other
0%	0%	50%	10%	40%	

Architectural Lighting & LPD

500 Lux	30.1 W/m²
46 ft-candles	2.8 W/ft²

System Types

INC	CFL	T12ES	T8Magnetc	T8Electron	Other
25%	15%	30%	0%	30%	

Overall LPD	17.9 W/m²	1.7 W/ft²
Plug Loads (office equipment) EPD	7.7 W/m²	0.7 W/ft²

Ventilation:

System Type

CAV	VAV	DD	IU	100%OA	Other
50%	50%	0%	0%	0%	

System air Flow	5.4 L/s m²	1.07 CFM/ft²
Fan Power	12.3 W/m²	1.14 W/ft²

Cooling Plant:

System Type

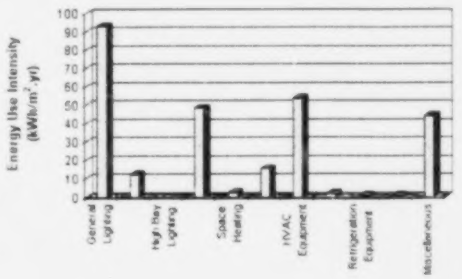
Centrifugal	Centri HE	Recip Open	DX	LiBr	Other
85%	0%	15%	0%	0%	

Calculated Capacity	113 W/m²	336 ft²/Ton

Cooling Plant Auxiliaires

Circulating Pumps	1.2 W/m²	0.1 W/ft²
Condenser Pumps	1.1 W/m²	0.1 W/ft²
Condenser Fan Size	2.3 W/m²	0.2 W/ft²

Baseline Energy Use



Energy Performance Summary

End-Use	**kWh/m².yr**	**kWh/ft².yr**
General Lighting	93	8.7
Architectural Lighting	12	1.2
High Bay Lighting	0	0.0
Plug Loads & Office Equipment	49	4.5
Space Heating	3	0.2
Space Cooling	15	1.4
HVAC Equipment	54	5.0
DHW	2	0.2
Refrigeration Equipment	1	0.1
Food Service Equuipment	1	0.1
Miscellaneous	44	4.1
Total	**275**	**25.5**
	W/m²	**W/ft²**
Peak Demand	63	5.9

The small commercial building segment shown in Section 2.2 was not subjected to the same level of analysis as the remaining building segments. Rather, electricity consumption, by end use, within these smaller buildings was estimated according to the detailed modelled results for each of the large- and medium-sized buildings.

2.4 DERIVATION OF SATURATION AND FUEL SHARE DATA

To derive fuel share and cooling saturation data for use in generating the detailed building profiles, annual electricity consumption data were broken into two base-load categories: one sensitive to heating weather and the other sensitive to cooling weather. This was achieved through analysis of BC Hydro's monthly consumption sales data to derive a base load during the shoulder months, as well as electricity consumption above the base load during the summer and winter. The analysis was conducted for each segment and for each region to provide a more detailed level of analysis and consequently more reliable fuel share and saturation data than in the previous CPR.

Exhibit 2.2 shows the electric fuel share for each combination of building segment and service region that match the weather-sensitive consumption calculated from the billing analysis. The actual weather-sensitive consumption for each of the building segments in each of the service regions is shown in Appendix C.

Exhibit 2.2: Estimated Electric Fuel Share by Building Segment and Service Region,[20] (%)

Segment	Lower Mainland		Vancouver Island		Interior	
	Space Heat %	DHW %	Space Heat %	DHW %	Space Heat %	DHW %
Large Office	5%	30%	22%	30%	10%	25%
Medium Office	10%	30%	20%	30%	20%	30%
Large Non-Food Retail	5%	50%	9%	50%	5%	40%
Medium Non-Food Retail	5%	50%	6%	50%	12%	50%
Food Retail	10%	20%	12%	20%	10%	20%
Large Hotel	10%	5%	19%	19%	90%	90%
Medium Hotel/Motel	20%	20%	41%	41%	10%	15%
Hospital	0%	0%	2%	2%	1%	0%
Nursing Homes	15%	10%	10%	10%	1%	5%
Large School	10%	10%	15%	13%	10%	10%
Medium School	5%	10%	13%	13%	7%	10%
University/College	3%	10%	6%	10%	5%	10%
Restaurant/Tavern	0%	10%	15%	15%	0%	10%
Warehouse/Whsale	0%	5%	0%	5%	10%	10%
Mixed Use	10%	10%	13%	13%	10%	10%
	100%	100%	100%	100%	0%	0%
Small Commercial	12%	15%	25%	25%	20%	10%

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[20] Fuel share estimates are based on an analysis of monthly consumption data provided by BC Hydro. The presence of zeros in Exhibit 2.2 indicates that no winter weather sensitive consumption was found in the data provided. The reader is reminded that the data provided were for the "modelled" building segments only. Consistent with the study's scope, only large- and medium-sized buildings were subject to detailed modelling. Further detail is provided in Appendix C.

2.5 FLOOR AREA CALCULATION

Floor area was derived by dividing the actual sales data for each building segment by the applicable fuel share and saturation-weighted, whole-building electricity use intensity (EUI). Exhibit 2.3 shows the resulting estimates of floor area within each building segment and service region. Floor area estimates were compared with available data from the Building Owners and Managers Association (British Columbia) and were found to provide a good match.

Exhibit 2.3: Estimated Floor Area by Building Segment[21] and Service Region, (sq. ft.)

Segment	Floor Area (sq.ft.)			
	Lower Mainland	Vancouver Island	Interior	Total
Large Office	43,690,000	5,290,000	1,462,000	50,442,000
Medium Office	10,090,000	2,350,000	1,480,000	13,920,000
Large Non-food Retail	25,630,000	5,420,000	4,970,000	36,020,000
Medium Non-food Retail	7,290,000	2,440,000	1,970,000	11,700,000
Food Retail	3,390,000	1,750,000	1,300,000	6,440,000
Large Hotel	8,740,000	1,130,000	790,000	10,660,000
Medium Hotel/Motel	3,650,000	1,250,000	1,150,000	6,050,000
Hospital	9,960,000	2,880,000	1,730,000	14,570,000
Nursing Homes	1,650,000	930,000	230,000	2,810,000
Large School	21,350,000	5,310,000	7,300,000	33,960,000
Medium School	11,220,000	4,880,000	6,000,000	22,100,000
University/College	20,660,000	4,050,000	1,750,000	26,460,000
Restaurant/Tavern	5,660,000	1,600,000	1,080,000	8,340,000
Warehouse/Whsale	19,710,000	2,110,000	1,170,000	22,990,000
Mixed Use	4,850,000	530,000	350,000	5,730,000
Small Commercial	164,420,000	56,950,000	65,300,000	286,670,000
Total	**361,960,000**	**98,870,000**	**98,032,000**	**558,862,000**

Overall, there is a relatively high level of confidence in the CEEAM whole-building EUIs. Similarly, significant effort has gone into refining the accuracy of the billing data provided by BC Hydro to the consultants. Consequently, the accuracy of floor space estimates should be in keeping with those of the EUI and billing data.

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[21] Restaurants in malls and office buildings are considered part of those buildings and their electricity use is categorized accordingly.

2.6 SUMMARY OF MODEL RESULTS

The summary of Base Year 2000–2001 model results are measured at the customer's point of use and do not include line losses; they are presented in four separate Exhibits:

- Exhibit 2.4 presents the model results for the total BC Hydro service area, with the results broken out by building segment and service region.
- Exhibits 2.5 to 2.7 inclusive present the same results, broken out by segment and end use for each of the three service regions defined for this CPR.

Highlights of the results for some end uses are as follows:

❑ Lighting

Lighting (general lighting, architectural lighting and high-bay lighting) is the major end use, and it accounts for 49% of the total electricity consumed. The analysis of available data showed high lighting power densities (LPDs) and long operating hours. For example, BC Hydro's Building Check-Up (BCU) database used to develop the building profiles suggested that the LPDs ranged from 0.7 to 3 W/sq.ft., with large offices running at 1.8 W/sq.ft. and large retail stores at 3 W/sq.ft. The resulting lighting EUIs were also high due to long hours of operation. (*See* Appendix A for details by building segment).

In offices, lighting accounts for 39% of total electricity use; in retail stores, lighting accounted for 66% of the total. Another contributor to the high connected load is the significant degree to which T12 lighting still persists in the commercial sector. BC Hydro's Commercial Survey (313 records) showed that in large offices, 50% of the stock (based on 50 office building records with a total floor area of 2.8 million sq. ft.) still uses T12 fluorescent lamps with electromagnetic ballasts.[22] Other segments showed slightly lower or slightly higher levels of T12 fluorescent lighting remaining.

❑ Heating Ventilation and Air-Conditioning Equipment

Heating Ventilation and Air-Conditioning Equipment (HVAC) is the second largest end use, accounting for 17% of the total electricity use. The largest contributors to high HVAC electricity use in commercial buildings are fan loads and long hours of operation. For example, office buildings are shown to have a connected fan load of 1.1 W/sq.ft., with an electricity use intensity of 4 kWh/sq.ft./yr. or 80% of the total HVAC equipment electricity use. Fans in non-food retail buildings are shown to have a similar connected load and account for 75% of the total HVAC equipment electricity use.

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[22] Note the survey also showed T12 lamps with electronic ballasts.

❑ Office Equipment and Plug Loads

This end use accounts for 10% of the total consumption and, with the miscellaneous end use, represents the next largest use of electricity. Data used to develop this end use comes from the BCU database and other sources. The office equipment and plug load estimate is very similar to the 9% value that was estimated in a recent U.S. Department of Electricity (DOE) study of office equipment and telecommunications electricity use in the U.S. commercial sector.[23] The office and hospital segments account for approximately 35% of the estimated electricity consumed by this end use.

❑ Electric Space Heat

This end use accounts for 4% of the total electricity use, an estimate that was derived from calibrating fuel shares to winter-weather–sensitive consumption for each commercial building segment.

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[23] Arthur D. Little, *Electricity Consumption by Office and Telecommunications Equipment in Commercial Buildings*, U.S. DOE, January 2002

Exhibit 2.4: Base Year (2000/01) Modelled Annual Electricity Consumption for the Total BC Hydro Service Area by Segment and End-use, (GWh/yr.) *(At customer's meter)*

End-use	End-uses											
Segment	General Lighting	Architectural Lighting	Other Lighting	Office Equip. & Plug Loads	Commercial Food Service	Commercial Refrigeration	Miscellaneous (Elev, Ext. Lghts)	Electric Space Heat	Space Cooling	Electric DHW	HVAC Equipment (Fans & Pumps)	Totals
Large Office	439	61		227	5	5	207	16	60	11	252	**1,283**
Medium Office	120	11		38	1	1	36	11	17	3	67	**305**
Large Non-food Retail	454	133		65	11	11	43	7	46	12	116	**898**
Medium Non-food Retail	166	12		20	2	2	13	3	10	3	33	**265**
Food Retail	103	9		19	3	200	10	4	9	2	25	**382**
Large Hotel	41	41		27	1	9	16	12	10	8	34	**197**
Medium Hotel/Motel	23	19		15	1	5	9	7	2	9	18	**108**
Hospital	9	41	38	55	1	6	12	2	14		77	**255**
Nursing Homes	8	6		4	0	2	3	5	1	1	9	**40**
Large School	143	14	14	27	3	3	10	18	2	2	79	**315**
Medium School	77	7	9	13			4	11	1	1	38	**162**
University/College	198	29		40	13	13	50	10	1	2	96	**453**
Restaurant/Tavern	81					27	148	1	10	3	30	**300**
Warehouse/Whsale	161	14		57		30	23	1	7	1	37	**330**
Mixed Use	5	14		5	2	4	5	4	0	2	2	**42**
Small Commercial	2,183	268	17	451	31	337	459	268	21	46	788	**4,869**
Total	**4,210**	**678**	**77**	**1,062**	**76**	**655**	**1,048**	**381**	**212**	**105**	**1,701**	**10,204**

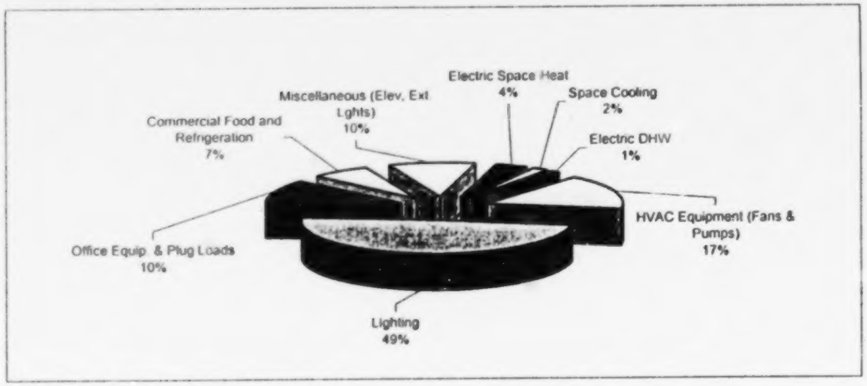


Exhibit 2.5: Base Year (2000/01) Modelled Annual Electricity Consumption for the Lower Mainland by Segment and End-use, (GWh/yr.) *(At customer's meter)*

End-use	End-uses											
Segment	General Lighting	Architectural Lighting	Other Lighting	Office Equip. & Plug Loads	Commercial Food Service	Commercial Refrigeration	Miscellaneous (Elev, Ext. Lghts)	Electric Space Heat	Space Cooling	Electric DHW	HVAC Equipment (Fans & Pumps)	Totals
Large Office	380	52		197	4	4	179	10	55	9	218	1,110
Medium Office	87	8		27	1	1	26	6	14	2	48	221
Large Non-food Retail	323	95		46	8	8	31	5	35	9	79	638
Medium Non-food Retail	104	7		12	1	1	8	1	7	2	20	165
Food Retail	54	5		10	2	105	5	2	4	1	13	200
Large Hotel	33	33		22	1	7	13	5	8	3	27	153
Medium Hotel/Motel	14	12		9	0	3	5	4	1	5	10	63
Hospital	6	28	26	38	1	4	8		10		52	172
Nursing Homes	5	4		2	0	1	2	4	0	1	5	24
Large School	90	9	9	17	2	2	6	9	1	1	47	193
Medium School	39	3	4	7			2	4	1	1	18	79
University/College	155	23		31	10	10	39	7	1	1	74	352
Restaurant/Tavern	55					18	100		8	2	20	203
Warehouse/Whsale	138	12		49		26	20		6	0	32	282
Mixed Use	4	12		4	2	3	4	3	0	1	1	35
Small Commercial	1,277	146	6	256	17	99	294	105	11	17	478	2,707
Total	**2,763**	**449**	**45**	**727**	**50**	**293**	**744**	**165**	**161**	**55**	**1,145**	**6,598**

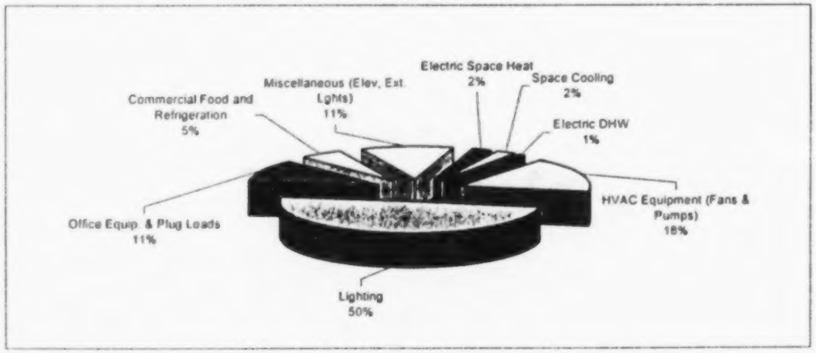


Exhibit 2.6: Base Year (2000/01) Modelled Annual Electricity Consumption for Vancouver Island by Segment and End-use, (GWh/yr.) *(At customer's meter)*

End-use / Segment	End-uses											
	General Lighting	**Architectural Lighting**	**Other Lighting**	**Office Equip. & Plug Loads**	**Commercial Food Service**	**Commercial Refrigeration**	**Miscellaneous (Elev, Ext. Lghts)**	**Electric Space Heat**	**Space Cooling**	**Electric DHW**	**HVAC Equipment (Fans & Pumps)**	**Totals**
Large Office	46	6		24	1	1	22	5	3	1	26	**135**
Medium Office	20	2		6	0	0	6	3	1	0	11	**51**
Large Non-food Retail	68	20		10	2	2	7	2	3	2	17	**132**
Medium Non-food Retail	35	2		4	0	0	3	1	1	1	7	**54**
Food Retail	28	2		5	1	54	3	1	2	0	7	**104**
Large Hotel	4	4		3	0	1	2	1	1	1	4	**21**
Medium Hotel/Motel	5	4		3	0	1	2	3	0	3	4	**24**
Hospital	2	8	7	11	0	1	2	1	3		15	**51**
Nursing Homes	3	2		1	0	1	1	1	0	0	3	**13**
Large School	22	2	2	4	1	1	2	4		0	12	**49**
Medium School	17	1	2	3			1	4		0	8	**37**
University/College	30	4		6	2	2	8	3		0	15	**70**
Restaurant/Tavern	16					5	28	1	1	1	6	**58**
Warehouse/Whsale	15	1		5		3	2		0	0	3	**30**
Mixed Use	0	1		0	0	0	0	0		0	0	**4**
Small Commercial	398	51	4	89	7	109	99	79	4	23	140	**1,002**
Total	**709**	**113**	**16**	**175**	**14**	**181**	**187**	**108**	**21**	**34**	**277**	**1,835**

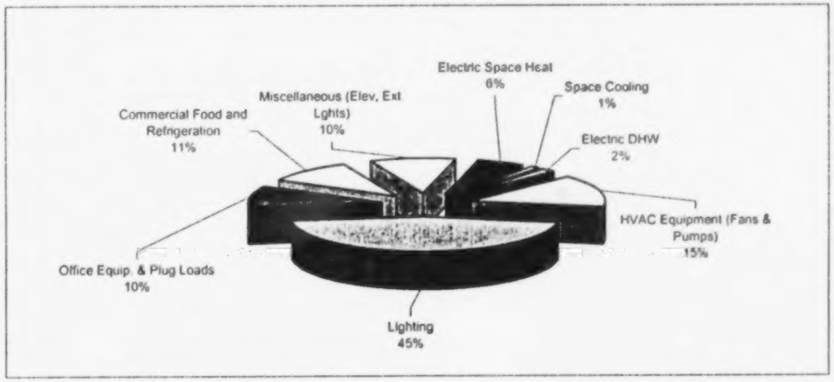
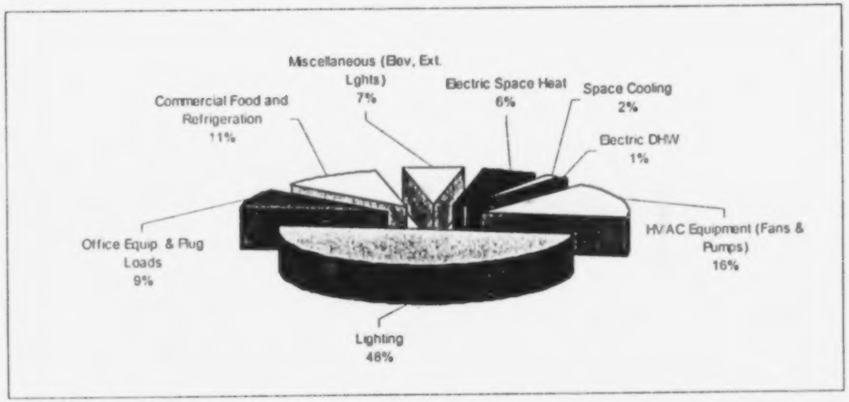


Exhibit 2.7: Base Year (2000/2001) Modelled Annual Electricity Consumption for the Interior by Segment and End-use, (GWh/yr.) *(At customer's meter)*

End-use	End-uses											
Segment	General Lighting	Architectural Lighting	Other Lighting	Office Equip. & Plug Loads	Commercial Food Service	Commercial Refrigeration	Miscellaneous (Elev, Ext. Lghts)	Electric Space Heat	Space Cooling	Electric DHW	HVAC Equipment (Fans & Pumps)	Totals
Large Office	13	2		7	0	0	6	1	2	0	7	**38**
Medium Office	13	1		4	0	0	4	2	2	0	7	**34**
Large Non-food Retail	63	18		9	1	1	6	1	7	1	19	**128**
Medium Non-food Retail	28	2		3	0	0	2	1	2	0	6	**46**
Food Retail	21	2		4	1	40	2	1	2	0	5	**78**
Large Hotel	3	3		2	0	1	1	6	1	3	3	**23**
Medium Hotel/Motel	4	4		3	0	1	2	1	0	1	4	**20**
Hospital	1	5	4	7	0	1	1	0	2		10	**32**
Nursing Homes	1	1		0	0	0	0	0	0	0	1	**3**
Large School	31	3	3	6	1	1	2	5	1	0	20	**73**
Medium School	21	2	2	4			1	3	1	0	13	**47**
University/College	13	2		3	1	1	3	1	0	0	7	**31**
Restaurant/Tavern	10					3	19		1	0	4	**39**
Warehouse/Whsale	8	1		3		2	1	1	0	0	2	**18**
Mixed Use	0	1		0	0	0	0	0	0	0	0	**3**
Small Commercial	508	70	7	106	7	129	65	85	7	7	170	**1,160**
Total	**737**	**116**	**16**	**160**	**12**	**181**	**117**	**108**	**30**	**15**	**279**	**1,772**



2.7 COMPARISON WITH BC HYDRO BILLING DATA

This section compares the actual BC Hydro billing data for each building segment and Service region with the modelled results presented previously in subsection 2.2. As illustrated in Exhibit 2.8, the modelled results match exactly with the BC Hydro billing data. This exact match occurs because (as noted in subsection 2.5) model results have been calculated starting with actual billing data and then dividing by the building electricity use intensities (EUIs) to determine floor area in each building segment.

Exhibit 2.8: Base Year (2000/01) Annual Electricity Consumption, for BC Hydro Actual versus Model Estimates, (GWh/yr.)**

Segment	Lower Mainland			Vancouver Island			Interior			Total		
	BCH	Model	diff.%	BCH	Model	diff.%	BCH	Model	diff.%	BCH	Model	diff.%
Large Office	1,110	1,110	0	135	135	0	38	38	0	1,283	1,283	0
Medium Office	221	221	0	51	51	0	34	34	0	305	305	0
Large Non-food	638	638	0	132	132	0	128	128	0	897	897	0
Medium Non-food	165	165	0	54	54	0	46	46	0	266	266	0
Food Retail	200	200	0	104	104	0	78	78	0	382	382	0
Large Hotel	153	153	0	21	21	0	23	23	0	197	197	0
Medium	63	63	0	24	24	0	20	20	0	107	107	0
Hospital	172	172	0	51	51	0	32	32	0	255	255	0
Nursing Homes	24	24	0	13	13	0	3	3	0	40	40	0
Large School	193	193	0	50	50	0	73	73	0	315	315	0
Medium School	79	79	0	37	37	0	47	47	0	163	163	0
University/Colleg	352	352	0	70	70	0	31	31	0	453	453	0
Restaurant/Taver	204	203	0	58	58	0	39	39	0	300	300	0
Warehouse/Whsale	282	282	0	30	30	0	18	18	0	330	330	0
Mixed Use	35	35	0	4	4	0	3	3	0	41	41	0
Large & Medium	3,891	3,891	0	834	834	0	613	613	0	5,334	5,334	0
Small Commercial	2,707	2,707	0	1,002	1,002	0	1,160	1,160	0	4,869	4,869	0
Other Commercial Buildings	1,459	1,459	0	229	229	0	305	305	0	1,994	1,994	0
Other Non-buildings	338	338	0	45	45	0	156	156	0	539	539	0
Subtotal	**8,395**	**8,395**	**0**	**2,109**	**2,109**	**0**	**2,233**	**2,233**	**0**	**12,737**	**12,737**	**0**
* These segments were not subject to model analysis.												

**Results are measured at the customer's point of use and do not include line losses.

3. REFERENCE CASE

3.1 INTRODUCTION

This section presents the Commercial Sector Reference Case for the study period (FYs 2000/01 to 2015/16). The Reference Case estimates the expected level of electricity consumption that would occur over the study period in the absence of new Power Smart initiatives or rate changes.[24] The Reference Case, therefore, provides the point of comparison for the subsequent calculation of remaining economically attractive electricity savings opportunities.

The discussion is presented within the following subsections:

- Development of Detailed Profiles—New Buildings
- Expected Growth in Building Stock
- "Natural" Changes Affecting Electricity Consumption
- End-use Model Results
- Comparison with BC Hydro Forecasts.

3.2 DEVELOPMENT OF DETAILED PROFILES—NEW BUILDINGS

The first task in building the Reference Case involved the development of detailed technical profiles that define building specifications, mechanical equipment, lighting equipment and electricity use for the "new" buildings in each of the commercial building segments. In each case, the new building profiles were developed using Marbek's building electricity simulation model, CEEAM, and the same approach as described previously in the base-year discussion.

Exhibit 3.1 presents a sample New Building Profile. It summarizes the major technical assumptions that have been used for new offices in the development of the Reference Case. Detailed profiles for each new building segment are provided in Appendix D (Lower Mainland and Vancouver Island) and Appendix E (Interior)[25].

Exhibit 3.2 highlights the resulting whole-building EUIs for each new commercial building segment. For the purposes of reference, it also shows whole-building EUIs for each of the existing building segments, and these show significant declines for most segments. General factors that have reduced the EUIs for new buildings include the following:

- New linear fluorescent lighting is T8 with electronic ballasts;
- Improved thermal characteristics with insulation levels of R16 for roofs and R8 to R12 for walls;
- Double pane c/w thermal break window glazing (no single-pane glazing); and
- Improved cooling equipment efficiencies (centrifugal chiller efficiencies are 0.58 kW/ton and packaged equipment EERs are 9 to 9.5).

[**Note**: the measure of imperial ton is used throughout the Commercial sector report.]

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[24] Some limited residual program influences remain from the earlier Power Smart initiatives.

[25] A glossary of terms and a list of abbreviations used in the Building Profiles are presented as sections 11 and 12, respectively.

Exhibit 3.1: Sample New Large Office

Summary Building Profile

Building Type: New Large Office	**Location:** Lower Mainland
Description: This archetype is based on knowledge of current commercial construction practices seen in BC Hydro's Design Assistance Program and NRCan's CBIP program	**The Average Building:** The average building characteristics used to define this building profile are as follows - average building size 230,000 ft² - average footprint 12,100 ft² assumes a 110 ' x 110 ' footprint - 19 stories

Building Specifications:

roof construction	0.24 W/m² °C	0.04 Btu/hr ft² °F
wall construction	0.71 W/m² °C	0.13 Btu/hr ft² °F
windows	2.8 W/m² °C	0.49 Btu/hr ft² °F
shading coefficient	0.45	
window to wall ratio	0.6	

General Lighting & LPD	440 Lux	11.4 W/m²
	41 ft-candles	1.1 W/ft²

System Types

INC	CFL	T12ES	T8Magnetic	T8Electron	Other
0%	0%	0%	0%	100%	

Architectural Lighting & LPD	300 Lux	13.0 W/m²
	28 ft-candles	1.2 W/ft²

System Types

INC	CFL	T12ES	T8Magnetic	T8Electron	Other
10%	30%	0%	0%	60%	

Overall LPD	10.8 W/m²	1.0 W/ft²
Plug Loads (office equipment) EPD	7.8 W/m²	0.7 W/ft²

Ventilation:

System Type

CAV	VAV	DD	IU	100%OA	Other
10%	90%	0%	0%	0%	

System air Flow	5.5 L/s m²	1.08 CFM/ft²
Fan Power	9.3 W/m²	0.86 W/ft²

Cooling Plant:

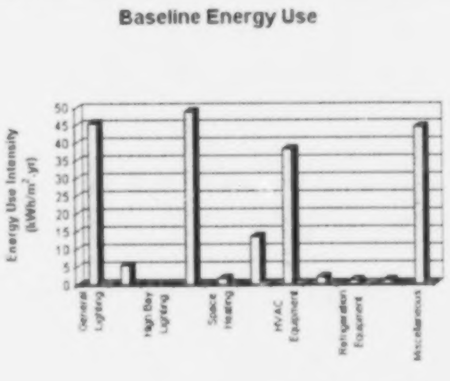
System Type

Centrifugal	Centn HE	Recip Open	DX	LiBr	Other
0%	75%	25%	0%	0%	

Calculated Capacity	102 W/m²	371 ft²/Ton

Cooling Plant Auxiliaires

Circulating Pumps	1.1 W/m²	0.1 W/ft²
Condenser Pumps	1.0 W/m²	0.1 W/ft²
Condenser Fan Size	2.0 W/m²	0.2 W/ft²


Baseline Energy Use

Energy Performance Summary

End-Use	kWh/m².yr	kWh/ft².yr
General Lighting	46	4.2
Architectural Lighting	5	0.5
High Bay Lighting	0	0.0
Plug Loads & Office Equipment	49	4.5
Space Heating	2	0.1
Space Cooling	13	1.3
HVAC Equipment	38	3.5
DHW	2	0.2
Refrigeration Equipment	1	0.1
Food Service Equipment	1	0.1
Miscellaneous	44	4.1
Total	202	18.8
	W/m²	W/ft²
Peak Demand	47	4.4

Exhibit 3.2: Comparison of Whole Building EUIs or BEPI for the Lower Mainland, (kWh/sq.ft./yr.)

Segment	Existing Buildings	New Buildings	Comments
Large Office	25.6	18.8	Most of the reduction is attributable to lighting. New construction is based on 1.1 W/sq.ft. vs. 1.7 W/sq.ft. for existing.
Medium Office	22.0	18.0	Similar to the large office.
Large Non-food Retail	24.8	22.5	Some lighting reduction from use of T8 lighting.
Medium Non-food Retail	23.0	21.7	Some lighting reduction from use of T8 lighting.
Food Retail	60.9	54.9	Some lighting reduction from use of T8 lighting.
Large Hotel	17.6	14.4	Higher use of CFL in suites and corridors compared to existing hotels.
Medium Hotel/Motel	17.9	13.9	Similar to large hotels.
Hospital	17.3	18.2	Electricity intensities increase due to higher fan power from increased filtration, higher heating loads and cooling loads.
Nursing Homes	15.1	13.9	Lighting reduction from use of T8.
Large School	8.7	9.3	Higher ventilation rates and more fan electricity use offsets lighting reductions.
Medium School	7.1	7.1	Similar to large schools.
University/College	17.2	13.3	Lighting reduction from use of T8.
Restaurant	39.6	37.5	Lighting reduction from use of T8 and CFLs.
Warehouse/Wholesale	14.4	12.4	Some lighting reduction.

Exhibit 3.2 also shows that the whole-building EUIs increase in some segments, the major contributing factors to this increase including:

- New design practices that require higher ventilation rates in selected segments, such as in schools and hospitals, with a net overall increase in whole building electricity use; and
- Increased saturation of space cooling in selected segments.

3.3 EXPECTED GROWTH IN BUILDING STOCK

The next step in developing the Reference Case involved the development and application of estimated levels of floor space growth in each building segment and service region over the study period. BC Hydro's 2000 Forecast provided the core stock growth rates. However, due to differences in building segment definition between the BC Hydro 2000 Forecast and this analysis and the absence of service region breakouts in the 2000 forecast, it was necessary to derive estimated growth rates from the data provided.

Exhibit 3.3 summarizes the growth rates employed. Major assumptions employed include:

- "Large Office" growth rates were used for both large and medium offices.
- "Non-Food Retail" growth rates were used for both large and medium non-food retail.
- "Hotel/Motel" growth rates were used for both large and medium hotels.

- "Education Facilities" growth rates were used for large schools, medium schools and university/colleges.
- "Apartment" growth rates were used for the mixed-use buildings.
- "Other Commercial Building" growth rates were used for the small commercial segment.[26]
- As the regional growth rates did not include estimates for the 2010–15 period, provincial estimates were used instead.

3.4 "NATURAL" CHANGES AFFECTING ELECTRICITY CONSUMPTION

The next task involved estimation of expected "natural" changes in electricity consumption patterns over the study period with consideration of three major factors:

- "Naturally occurring" improvements in equipment efficiency;
- Expected stock penetration by more efficient equipment; and
- Changes in the saturation of end-use services (e.g., cooling, plug loads etc.).

These factors will strongly influence future electricity use within the commercial sector. While the first two factors will have the affect of reducing electricity consumption, the last factor will result in increased electricity demand. Other considerations, such as operating hours, fuel share, etc., may also affect future electricity demand. However, the values assumed in existing and new stock were assumed to remain constant over the study period.

Based on the assessment of current trends, the most significant "natural" changes are expected to involve the following three end uses:

- Lighting;
- Space cooling; and
- Plug loads.

Further discussion of the expected "natural" changes affecting the above end uses follows. In each case, the discussion identifies the technical change, the major "driver(s)" and the assumed electricity impact.

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[26] There is some uncertainty regarding the correct value to use for small commercial growth. For example use of a straight average of the growth rates for all the large and medium commercial segments would result in a rate of approximately 2.72% rather the 3% value that was selected which, as noted in the text, is the rate employed by BCH for "Other" commercial buildings.

Exhibit 3.3: Commercial Sector Floor Space Growth Rates (% annum)

Commercial Segments	Lower Mainland			Vancouver Island			Interior Region		
	Period 2000-2005	Period 2005-2010	Period 2010-2015	Period 2000-2005	Period 2005-2010	Period 2010-2015	Period 2000-2005	Period 2005-2010	Period 2010-2015
Large Office	2.2%	2.7%	2.2%	2.1%	2.0%	2.2%	2.5%	2.5%	2.2%
Medium Office	2.2%	2.7%	2.2%	2.1%	2.0%	2.2%	2.5%	2.5%	2.2%
Large Non-Food Retail	3.2%	3.4%	2.6%	3.2%	3.5%	2.6%	3.0%	2.8%	2.6%
Medium Non-Food Retail	3.2%	3.4%	2.6%	3.2%	3.5%	2.6%	3.0%	2.8%	2.6%
Food Retail	2.9%	2.7%	2.4%	1.6%	1.7%	2.4%	1.9%	2.4%	2.4%
Large Hotel	3.6%	3.5%	2.5%	1.7%	2.1%	2.5%	2.8%	2.9%	2.5%
Medium Hotel/Motel	3.6%	3.5%	2.5%	1.7%	2.1%	2.5%	2.8%	2.9%	2.5%
Hospital	2.4%	2.2%	1.8%	3.0%	2.9%	1.8%	2.7%	2.7%	1.8%
Nursing Homes	3.4%	3.7%	2.4%	1.3%	2.3%	2.4%	2.6%	3.4%	2.4%
Large School	2.2%	2.3%	2.2%	0.2%	0.6%	2.2%	1.9%	2.2%	2.2%
Medium School	2.2%	2.3%	2.2%	0.2%	0.6%	2.2%	1.9%	2.2%	2.2%
University/Colleges	2.2%	2.3%	2.2%	0.2%	0.6%	2.2%	1.9%	2.2%	2.2%
Restaurant/Tavern	2.4%	2.5%	2.2%	2.1%	2.1%	2.2%	2.7%	2.6%	2.2%
Warehouse/Whsale	2.8%	3.0%	2.3%	2.0%	3.2%	2.3%	2.5%	2.5%	2.3%
Mixed Use	2.3%	2.5%	2.4%	2.3%	2.5%	2.4%	2.3%	2.5%	2.4%
Small Commercial	3.0%	3.1%	3.0%	3.5%	3.3%	3.0%	2.3%	2.3%	2.0%
Other Commercial Building	3.0%	3.1%	3.0%	3.5%	3.3%	3.0%	2.3%	2.3%	2.3%
Other Non-Buildings	1.7%	2.0%	2.0%	2.2%	2.0%	2.0%	1.3%	1.8%	1.8%

3.4.1 Lighting

As a result of natural conservation, it is assumed that the replacement of existing T12 fluorescent lighting and electromagnetic ballasts with new T8 fluorescent lamps and electronic ballasts will continue. Similarly, compact fluorescent lamps (CFL) lamps will continue to increase their market share over incandescent lamps, particularly in segments such as hotels and retail.

The continued growth of CFLs and T8 lighting/electronic ballasts is being driven by:

- Further price decreases and increased consumer recognition of the operating cost savings; and
- Revised electricity performance regulations, such as the U.S.DOE/Canada ballast rules. This updated regulation will require all new 4- and 8-ft. luminaires to use electronic ballasts by 2005. Other ballasts intended for the replacement market must be electronic after 2010.[27]

Overall, the Reference Case assumes that, by 2015, a further 50% of the remaining T12 stock will be replaced with T8 electronic systems.

3.4.2 Space Cooling

As a result of natural conservation, it is assumed new chillers and DX equipment will provide improved electricity performance compared to existing equipment. New centrifugal chillers achieve average performance efficiencies of 0.55 to 0.65 kW/ton (average of 0.58 kW/ton). New DX equipment achieves average performance efficiencies of EER 9 to 9.5.

It is assumed that the existing non-CFC[28] refrigerant regulations, which banned R11 and R12, will continue to drive chiller replacements. It is estimated that 50% of the CFC chillers have been replaced to date.[29] The Reference Case assumes that a further 40% of existing CFC-based chillers will have been replaced with non-CFC models by 2015, with a resulting increase in efficiency.

In addition to the above efficiency improvements, this end use (space cooling) is expected to experience a modest increase in saturation levels, as shown in Exhibit 3.4. Depending on building segment, this increase in saturation levels offsets some of the effects of the increased chiller efficiency.

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[27] "Lighting Tidbits," *E Source E News* (July 2002).

[28] CFC is chlorofluorocarbon.

[29] "Chiller Phaseout Slows," *ASHRAE Journal* (May 2002), p. 11.

Exhibit 3.4: Reference Case for Space Cooling Saturations, (%)

Segment	A/C Saturation Existing Buildings Year 2000 (%)	A/C Saturation Existing Buildings Year 2015 (%)
Large Office	90	90
Medium Office	90	90
Large Non-food Retail	85	90
Medium Non-food Retail	80	85
Food Retail	90	90
Large Hotel	80	90
Medium Hotel/Motel	40	50
Hospital	80	90
Nursing Homes	25	65
Large School	5	15
Medium School	5	15
Universities and Colleges	3	3
Restaurant/Tavern	75	80
Warehouse/Wholesale	30	30
Mixed Use	5	10

3.4.3 Plug Loads

Office equipment plug loads continue to grow as a result of increased density of computer use per occupant, increased use of network computers and servers and growth in other peripherals, such as telephone network equipment. Estimates of likely future growth were based on a January 2002 report prepared for the U.S. Department of Electricity (DOE).[30] The report presents three growth rate scenarios,[31] as follows:

1) **"Greening of IT".** This low-growth scenario estimates a negative growth rate of –3% per year; it assumes that, because of the Kyoto Accord, electrical efficiency in office equipment will become an imperative concern.

2) **"Ubiquitous Computing".** This intermediate-growth scenario estimates a positive growth rate of 2.6% per year. In this scenario, the saturation of computer equipment continues to grow and extends to newer devices, such as handheld computers and wireless phones. This scenario assumes little reduction in electricity use resulting from the Electricity Star program, reduced standby power or the increased use of flat panel displays.

3) **"PC Reigns".** This high-growth scenario estimates annual growth rates to be 4.7% per year. This scenario assumes an increased reliance on desktop computers driven, in part, by continued increases in data exchange and Internet computing. It assumes no reduction in electricity use resulting from the Electricity Star program, reduced standby power features or the increased use of flat panel displays.

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[30] Arthur D. Little, *Electricity Consumption by Office and Telecommunication Equipment in Commercial Buildings*. U.S. DOE, Ref. 72895-00 (January 2002)

[31] Reported growth rates refer to annual electricity consumption by this equipment category.

As noted above, neither the intermediate- nor the high-growth scenario takes into account natural conservation occurring as a result of the Electricity Star program, better standby power features, migration towards laptop computers (as prices continue to drop) or replacement of CRT monitors with flat panel displays by 2010.[32, 33] Consequently, neither scenario appears to be realistic. A more realistic scenario is believed to be one in between the low- and intermediate-growth scenarios that takes into account a reduction in the power use of computers and monitors due to the trends mentioned above. The growth rate posited for this alternate scenario was approximately equal to an annual growth rate of 0.9%.

Given the above, an annual growth rate of 0.9% was applied to offices. Hospitals were assumed to experience a higher growth rate of 1.9% per year due to a higher penetration of diagnostic equipment, a higher growth in computing power necessitated by 3-D visualization/imaging and increased used of electronic databases.

3.4.4 Impact on Electricity Use

The net impact on building electricity use from the "natural" changes noted above will be equivalent to an overall reduction in building electricity that ranges from 1% for office buildings to 6% in hotels. Hospitals, however, experience an EUI increase of approximately 6% due to the combination of higher plug loads from increased diagnostic equipment and increased air filtration requirements (with associated heating and cooling impacts).[34]

Exhibit 3.5 summarizes the EUIs changes and presents a breakdown of the electricity savings that are expected to occur in the large office segment as a result of these changes. As illustrated, lighting and cooling end uses experience a reduction due to the introduction of T8 lighting and new more efficient chillers. Plug loads, however, increase by an estimated 14%.

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[32] Flat panel displays will likely become the standard entry level after 2005, as they have a lower manufacturing cost compared to current CRT monitors.

[33] "Flat Panel Displays: Changing the Picture for Desktop Computer Monitors," *E Source E News* (May 2000).

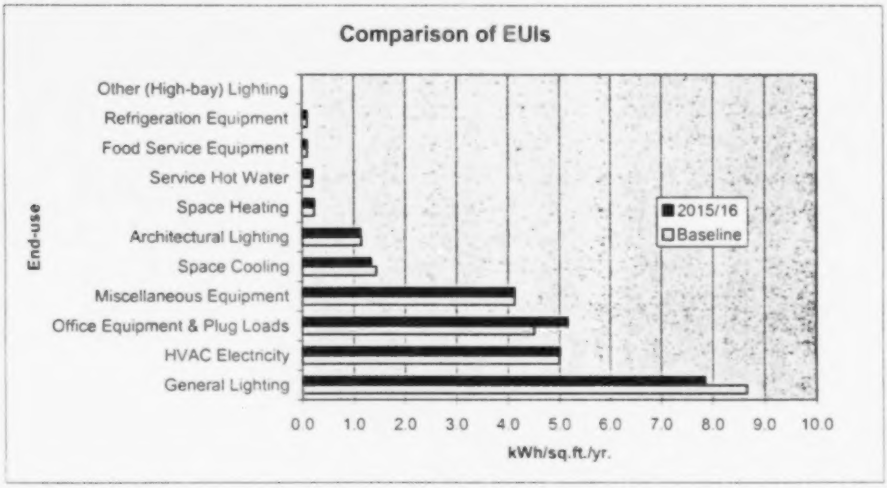
[34] Interactive effects are fully accounted for, as all electricity impacts are based on modelled results.

Exhibit 3.5: Comparison of Annual Electricity Use by End Use for Base Year versus 2015/16 for Large Offices in Lower Mainland*

Comparison of EUIs

Large Office **Lower Mainland**

End-use	Baseline		2015/16		% Reduction
	MJ/m^2/yr	Wh/sq ft /y	MJ/m^2/yr	Wh/sq ft /y	
General Lighting	335	8.7	304	7.8	9%
HVAC Electricity	194	5.0	194	5.0	0%
Office Equipment & Plug Loads	175	4.5	200	5.2	-14%
Miscellaneous Equipment	160	4.1	160	4.1	0%
Space Cooling	56	1.4	52	1.3	6%
Architectural Lighting	45	1.2	44	1.1	1%
Space Heating	9	0.2	9	0.2	0%
Service Hot Water	8	0.2	8	0.2	0%
Food Service Equipment	4	0.1	4	0.1	0%
Refrigeration Equipment	4	0.1	4	0.1	0%
Other (High-bay) Lighting	0	0.0	0	0.0	0%
Total	**989**	**25.5**	**978**	**25.3**	**1%**



* Negative reduction shown above for office equipment and plug loads reflects an increased EUI.

3.5 END-USE MODEL RESULTS

The Reference Case results are presented in four separate exhibits:

Exhibit 3.6 presents the model results for the total BC Hydro service area, with the results being broken out by building segment and milestone year.

Exhibits 3.7 to 3.9 inclusive present the same results for each of the three service regions defined for this CPR.

Exhibit 3.6: Reference Case for Annual Electricity Consumption in the Total BC Hydro Service Area, (GWh/yr.)*

Segment	2000/01	2005/06	2010/11	2015/16
Large Office	1,283	1,390	1,531	1,665
Medium Office	305	335	371	407
Large Non-food Retail	898	1,035	1,201	1,348
Medium Non-food Retail	265	308	359	405
Food Retail	382	426	476	532
Large Hotel	198	226	257	282
Medium Hotel/Motel	108	121	137	150
Hospital	255	292	328	363
Nursing Homes	40	46	54	60
Large School	315	346	384	431
Medium School	162	176	194	216
University/College	453	487	526	571
Restaurant/Tavern	300	336	378	420
Warehouse/Whsale	330	371	423	468
Mixed Use	42	47	53	59
Small Commercial	4,869	5,543	6,324	7,082
Other Commercial Buildings	1,141	1,316	1,519	1,752
Other Non-buildings	1,392	1,514	1,672	1,846
Total	**12,739**	**14,314**	**16,185**	**18,056**

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 3.7: Reference Case for Annual Electricity Consumption in the Lower Mainland, (GWh/yr.)*

Segment	2000/01	2005/06	2010/11	2015/16
Large Office	1,110	1,202	1,328	1,443
Medium Office	221	241	269	294
Large Non-food Retail	638	736	856	960
Medium Non-food Retail	165	191	224	253
Food Retail	200	229	260	291
Large Hotel	153	177	202	222
Medium Hotel/Motel	63	73	83	91
Hospital	172	195	216	238
Nursing Homes	24	29	34	39
Large School	193	216	243	272
Medium School	79	88	98	109
University/College	352	383	417	453
Restaurant/Tavern	203	228	257	286
Warehouse/Wholesale	282	318	363	401
Mixed Use	35	39	44	50
Small Commercial	2,707	3,086	3,541	4,025
Other Commercial Buildings	858	990	1,142	1,317
Other Non-buildings	940	1,023	1,129	1,247
Total	**8,396**	**9,444**	**10,706**	**11,990**

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 3.8: Reference Case for Annual Electricity Consumption in Vancouver Island, (GWh/yr.)*

Segment	2000/01	2005/06	2010/11	2015/16
Large Office	135	146	157	171
Medium Office	51	56	60	66
Large Non-food Retail	132	153	179	201
Medium Non-food Retail	54	63	74	84
Food Retail	104	112	121	135
Large Hotel	21	22	24	26
Medium Hotel/Motel	24	26	28	31
Hospital	51	60	70	77
Nursing Homes	13	14	15	17
Large School	49	49	51	57
Medium School	37	37	38	42
University/College	70	71	72	78
Restaurant/Tavern	58	64	71	79
Warehouse/Wholesale	30	33	38	42
Mixed Use	4	4	5	6
Small Commercial	1,002	1,175	1,364	1,521
Other Commercial Buildings	140	162	186	215
Other Non-buildings	134	146	161	178
Total	**2,109**	**2,391**	**2,714**	**3,025**

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 3.9: Reference Case for Annual Electricity Consumption in the Interior, (GWh/yr.)*

Segment	2000/01	2005/06	2010/11	2015/16
Large Office	38	42	46	51
Medium Office	34	38	42	47
Large Non-food Retail	128	146	166	187
Medium Non-food Retail	46	53	61	68
Food Retail	78	85	95	107
Large Hotel	24	27	30	34
Medium Hotel/Motel	20	22	25	28
Hospital	32	36	42	47
Nursing Homes	3	3	4	4
Large School	73	80	91	102
Medium School	47	51	58	64
University/College	31	34	37	40
Restaurant/Tavern	39	44	50	55
Warehouse/Wholesale	18	20	22	25
Mixed Use	3	3	3	4
Small Commercial	1,160	1,282	1,419	1,536
Other Commercial Buildings	143	165	190	220
Other Non-buildings	318	346	382	422
Total	**2,234**	**2,479**	**2,764**	**3,042**

*Results are measured at the customer's point of use and do not include line losses.

3.6 COMPARISON WITH BC HYDRO FORECAST

Exhibit 3.10 compares the modelled results and the BC Hydro Forecast (December 2000). As illustrated, the modelled Reference Case matches the BC Hydro Forecast very closely. As is also noted in Exhibit 3.10, it was necessary to account for three considerations:

- In the actual 2000/01 billing data, which provided the starting point for the modelled Reference Case, values differed slightly from the estimated value contained in the BC Hydro Forecast.
- Irrigation and pipeline transport electricity use is included in the commercial sector of BC Hydro's Forecast but, for this CPR, it is included in the Industrial Sector analysis.

Exhibit 3.10: Comparison of BC Hydro Forecast versus Model Results for the Total Commercial Sector, (GWh/yr.)

Milestone Year	BCH Published Forecast	Actual BCH Sales	Less: CPR Adjustments				CPRU Ref Case Case	Variance %
			To Actual Sales	Removed from CPR	Transfer to Industry	Net for CPR Comparison		
2000/01	13,654	13,542	112	719	87	12,736	12,739	0%
2005/06	15,549		129	829	95	14,496	14,314	1%
2010/11	17,443		149	957	105	16,232	16,185	0%
2015/16	19188		172	1,104	115	17,797	18,056	-1%

Notes:

- Milestone adjustments assume the same growth rates as in the BC Hydro Forecast.
- A growth rate of 2.9% per year was applied to the first two adjustment columns (112 and 719 GWh); this is the rate used for “ Other Buildings”.
- The third column (87 GWh) refers to irrigation; the non-building growth rate of 1.7% per year was applied to the first milestone and 2% per year for the subsequent milestone years.

4. ENERGY EFFICIENCY UPGRADE OPTIONS

4.1 INTRODUCTION

This section identifies and assesses technical options for improving energy efficiency within the commercial sector. The discussion is organized using the same energy end uses as in the preceding sections of this report. For each end use, this section:

- Provides a brief description of the energy services provided;
- Identifies the baseline technology (or technologies) and/or practices;
- Identifies the applicable electrical efficiency upgrade options;
- Provides performance and cost data for both baseline and upgrade technologies; and
- Calculates the Cost of Conserved Energy (CCE) associated with each upgrade option.

4.1.1 Cost of Conserved Energy

One of the important sets of information provided in this section is the Cost of Conserved Energy (CCE)[35] associated with each energy efficiency upgrade option. The CCE for an energy efficiency upgrade is defined as the annualized incremental cost of the upgrade measure divided by the annual energy savings achieved, excluding any administrative or program costs required to achieve full use of the technology or measure. All cost information presented in this section and in the accompanying tables (*see* Appendix F) are constant (2002) dollars.

The CCE provides a basis for the subsequent selection of measures to be included in the Economic Potential Forecast (*see* Section 5). The CCE is calculated according to the following formula.

$$\frac{C_A + M}{S}$$

Where:

C_A is the annualized installed cost
M is the incremental annual cost of operation and maintenance (O & M)
S is the annual kWh energy savings.

And A is the annualization factor.

$$A = \frac{i(1+i)^n}{(1+i)^n - 1}$$

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[35] The term CCE that is used in this study refers to the same methodology as was used in the original CPR. However, in the original CPR, the term Total Resource Cost (TRC) was used. In both CPRs, program and administrative costs were excluded.

Where:

i is the discount rate
n is the life of the measure.

The CCE tables (*see* Appendix F) show both "incremental" and "full" installed costs for the measures or technologies, as applicable. If the measure or technology is installed in a new facility, or at the point of natural replacement in an existing facility, then the "incremental" cost of the efficient measure versus the cost of the baseline technology is used.

If an operating piece of equipment is replaced, prior to the end of its life, by a more efficient model, then the "full" cost of the efficient measure is used. In both cases, the costs of the measures are annualized, based on the number of years of equipment life and the discount rate and, as applicable, incorporate any changes in annual O & M.

The annual saving associated with the efficiency measure is the difference in annual energy consumption with and without the measure. The CCE tables in Appendix F show two savings: "Energy Saving 1" and "Energy Saving 2." Energy Saving 1 is the annual electricity savings that occur at the customer's meter. Energy Savings 2 takes into account BC Hydro system losses. The CCE is calculated using Energy Savings 2, as this is the appropriate point of comparison with other electricity supply options. Based on discussions with BC Hydro personnel it was determined that electricity delivered to the Lower Mainland load centre provided the most appropriate point of comparison with other electricity supply options. For distribution customers, the system losses between the point of use and this Lower Mainland load centre are 7% (3% area transmission and 4% distribution).[36]

4.1.2 Discount Rate

The CCE calculation is sensitive to the chosen discount rate. In the CCE calculations that accompany this document, three discount rates are shown: 6%, 8% and 10%. Based on the recommendation of BC Hydro's Energy Planning Department, the 8% (net-of-inflation) discount rate was used for the primary CCE calculation. The CCEs were also calculated using the 6% and 10% discount rates to provide sensitivity analysis.

Selection of the appropriate discount rate to be used in this analysis was guided by the intended use of the study results. The CPR seeks to identify the economic potential for DSM in B.C. in terms of the Total Resource Cost (TRC) of each measure. The TRC indicates what is "economically efficient" from a provincial perspective. Therefore, the appropriate discount rate is the social opportunity cost of capital, which is the estimated average pre-tax rate of return on public and private investments in the provincial economy. The intent of this discount rate is to "level the playing field" between the public entity, BC Hydro's investment in new resources, and private investment in resources (DSM and power projects). In 1989, the provincial government directed that: "BC Hydro should use an 8% discount rate for long-term planning purposes with sensitivity ranges as appropriate."[37]

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[36] This approach omits bulk transmission losses of 5%; however, this is consistent with the approach being applied to other possible electricity options, such as small-scale renewable electricity. It is also consistent with the general assumption that the most likely future electricity supply options will be developed closer to the load rather that at remote sites, such as the historical large-scale hydroelectric developments.

4.2 SUMMARY OF RESULTS

Exhibit 4.1 summarizes the calculated CCEs. The exhibit is organized by major end use and shows:

- **Technology Upgrade Options**

These represent technical options for replacing the baseline technologies or practices that continue to be employed in at least a portion of the stock. The upgrade options provide the same level of energy service (e.g., light) but with greater efficiency. The target baseline technologies are identified in the text that is provided in the subsections that follow. Additional details on the existing market share of the baseline technologies are provided in the Building Profiles provided in Appendices A, B, D and F. As different building segments can have different hours of annual operation, and consequently differing CCEs, more than one baseline is provided for some end uses.

- **Existing or New Buildings**

For practical purposes, measures can apply to new buildings, existing buildings or both. Therefore, the vintage of buildings to which the measure may apply is indicated.

- **Cost of Conserved Energy**

The CCEs[38] are presented for three discount rates, as applicable, on a "full cost" and/or ""incremental" installation basis.

As illustrated by the Summary of Results presented in Exhibit 4.1,[37] more than 50 "bundles" of measures were analyzed. Further detail is provided in the following text.

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[37] Arguably, the 8% social opportunity of capital, estimated in 1989, may be a different value today. However, in the absence of a comprehensive review, the 8% was recommended for this CPR to reinforce the understanding that the discount rate is the social opportunity cost of capital.

[38] Technology costs typically decline as they gain greater market share, which results in a lower CCE. Where applicable, these mature technology costs have been estimated and have been identified in the technology cost information provided.

[39] Zeros in Exhibit 4.1 indicate that the cost of the upgrade option is the same as for the baseline technology, provided that the existing systems have reached the end of their life.

Exhibit 4.1: Summary of Commercial Technology CCEs

Category or End Use	Technology		Existing or New Buildings	CCEs (¢/kWh)					
				6.0% DR		8.0% DR		10.0% DR	
				Full	Incr.	Full	Incr.	Full	Incr.
General Lighting (Existing Buildings)	Upgrade 1	Relamp and reballast with T8 lighting system (operation of 3500 h/yr.)	Existing	7.0	0.0	8.2	0.0	9.4	0.0
		Relamp and reballast with T8 lighting system (operation of 5000 h/yr.)	Existing	4.9	0.0	5.7	0.0	6.6	0.0
	Upgrade 2	Relamp and reballast with low BF T8 lighting system (operation of 3500 h/yr.)	Existing	4.3	0.0	5.1	0.0	5.8	0.0
		Relamp and reballast with low BF T8 lighting system (operation of 5000 h/yr.)	Existing	3.0	0.0	3.5	0.0	4.1	0.0
	Upgrade 3	Relamp and reballast with next generation "Extreme System" T8 lighting system (operation of 3500 h/yr.)	Existing	4.5	1.4	5.4	1.7	6.2	2.1
		Relamp and reballast with next generation "Extreme System" T8 lighting system (operation of 5000 h/yr.)	Existing	3.2	1.0	3.7	1.2	4.4	1.4
	Upgrade 4	Lighting Redesign to 30-50 fc with T8 lighting systems to 0.7 W/sq.ft. (operation of 3500 h/yr.)	Existing	3.6	0.0	4.3	0.0	4.9	0.0
		Lighting Redesign to 30-50 fc with T8 lighting systems to 0.7 W/sq.ft. (operation of 5000 h/yr.)	Existing	2.5	0.0	3.0	0.0	3.4	0.0
	Upgrade 5	Lighting Redesign to 30-50 fc with next generation" Extreme System" T8 lighting systems to 0.6 W/sq.ft. (operation of 3500 h/yr.)	Existing	3.5	0.7	4.1	0.8	4.7	1.0
		Lighting Redesign to 30-50 fc with next generation "Extreme System" T8 lighting systems to 0.6 W/sq.ft. (operation of 5000 h/yr.)	Existing	2.5	0.5	2.9	0.6	3.3	0.7
	Upgrade 6	Full integrated lighting controls (Ergolight) to 0.5 W/sq.ft. (operation of 3500 h/yr.)	Existing	4.6	4.1	5.4	4.8	6.2	5.5
		Full integrated lighting controls (Ergolight) to 0.5 W/sq.ft. (operation of 5000 h/yr.)	Existing	3.2	2.9	3.8	3.4	4.4	3.9
General Lighting (New Construction)	Upgrade 1	Next generation "Extreme System" T8 lighting system (49W/fixture and operation of 3500 h/yr.)	New Const.	na	1.4	na	1.7	na	2.1
		Next generation "Extreme System" T8 lighting system (49W/fixture and operation of 5000 h/yr.)	New Const.	na	1.0	na	1.2	na	1.4
	Upgrade 2	Lighting Redesign to 30-50 fc with next generation "Extreme System" T8 lighting systems to 0.6 W/sq.ft. (operation of 3500 h/yr.)	New Const.	na	0.7	na	0.8	na	1.0
		Lighting Redesign to 30-50 fc with next generation "Extreme System" T8 lighting systems to 0.6 W/sq.ft. (operation of 5000 h/yr.)	New Const.	na	0.5	na	0.6	na	0.7
	Upgrade 3	Full integrated lighting controls (Ergolight) to 0.5 W/sq.ft. (operation of 3500 h/yr.)	New Const.	na	4.1	na	4.8	na	5.5
		Full integrated lighting controls (Ergolight) to 0.5 W/sq.ft. (operation of 5000 h/yr.)		na	2.9	na	3.4	na	3.9
Architectural Lighting	Upgrade 1	CFL 18 to 20W to replace 75W incandescent (operation of 3500 h/yr.)	Both	3.1	2.6	3.2	2.7	3.4	2.9
		CFL 18 to 20W to replace 75W incandescent (operation of 5000 h/yr.)	Both	3.3	3.0	3.4	3.1	3.5	3.2
	Upgrade 2	Whitel LED 40W to replace 75W incandescent (operation of 3500 h/yr.)	Both	5.0	4.3	5.5	4.7	5.9	5.1
		Whitel LED 40W to replace 75W incandescent (operation of 5000 h/yr.)	Both	4.9	4.4	5.2	4.7	5.5	5.0
	Upgrade 3	CFL 26W to replace 90W PAR incandescent lamp (operation of 3500 h/yr.)	Both	2.0	0.1	2.1	0.2	2.3	0.3
		CFL 26W to replace 90W PAR incandescent lamp (operation of 5000 h/yr.)	Both	2.7	1.4	2.9	1.5	3.0	1.6
High bay Lighting	Uipgrade 1	350W Pulse Start Metal Halide (MH) to replace 400W MH lamp (operation of 3500 h/yr.)	Both	17.8	0.5	20.2	0.6	22.7	0.7
		350W Pulse Start Metal Halide (MH) to replace 400W MH lamp (operation of 5000 h/yr.)	Both	12.5	0.4	14.1	0.4	15.9	0.5
	Upgrade 2	54W HIF T5 Linear Fluorescent to replace 400W MH lamp (operation of 3500 h/yr.)	Both	4.4	0.4	5.0	0.4	5.6	0.5
		54W HIF T5 Linear Fluorescent to replace 400W MH lamp (operation of 5000 h/yr.)	Both	3.1	0.3	3.5	0.3	3.9	0.3

Exhibit 4.1 (cont'd): Summary of Commercial Technology CCEs

Category or End Use	Technology		Existing or New Buildings	CCEs (¢/kWh)					
				6.0% DR		8.0% DR		10.0% DR	
				Full	Incr.	Full	Incr.	Full	Incr.
Building Envelope	Upgrade 1	New electrically heated high-rise building with GFP wall to R20 (WWR 0.6)	New Const.	na	4.6	na	5.2	na	5.9
		New electrically heated high-rise building with GFP wall to R20 (WWR 0.3)	New Const.	na	3.3	na	3.7	na	4.2
	Upgrade 2	New electrically heated high-rise building with VPI wall to R40 (WWR 0.6)	New Const.	na	77.0	na	87.3	na	98.3
		New electrically heated high-rise building with VPI wall to R40 (WWR 0.3)	New Const.	na	46.2	na	52.4	na	59.0
	Upgrade 3	New electrically heated high-rise building with high performance glass >R4 (WWR 0.6)	New Const.	na	10.1	na	12.1	na	14.2
		New electrically heated high-rise building with high performance glass >R4 (WWR 0.3)	New Const.	na	10.2	na	12.3	na	14.4
Recomm/ BAS/FMS	Upgrade 1	Recommissioning of existing office building	Existing	4.2	na	4.5	na	4.8	na
	Upgrade 2	2nd Generation BAS/FMS in existing office building	Existing	4.5	na	4.8	na	5.1	na
	Upgrade 3	Recommissioning and 2nd Generation BAS/FMS in existing office building	Existing	4.6	na	4.9	na	5.3	na
HVAC VSDs	Upgrade 1	Variable Speed Drives (VSDs) for chilled water circulating pumps (operation of 2000 h/yr.)	Both	3.8	na	4.3	na	4.8	na
Heating ACCHP	Upgrade 1	ACCHP in low-rise commercial building with high heating load (10 kWh/sq.ft/yr)	Both	na	4.1	na	4.4	na	4.7
		ACCHP in low-rise commercial building with low heating load (6 kWh/sq.ft./yr)	Both	na	5.2	na	5.6	na	6.0
Chiller 0.5kW/Ton	Upgrade 1	High Efficiency Chiller (0.5 kW/Ton)	Both	na	4.4	na	5.4	na	6.4
Refrigeration	Upgrade 1	Unequal capacity multiplexed compressors	Both	na	2.9	na	3.4	na	4.0
	Upgrade 2	Display cases door/cover upgrades	Both	na	2.7	na	3.2	na	3.7
	Upgrade 3	Floating head pressure control	Both	2.4	na	2.9	na	3.3	na
	Upgrade 4	Smart defrost controls	Both	5.1	na	5.9	na	6.8	na
DHW Low-flow Devices	Upgrade 1	Low-flow shower heads and faucet aerators	Both	0.7	na	0.8	na	0.9	na
E-Star Office Equip.	Upgrade 1	Energy Star compliant desktop computer	Both	na	0.0	na	0.0	na	0.0
New Construction	Upgrade 1	Low temperature distribution (LTD) and TES	New Const.	na	4.3	na	5.3	na	6.5
	Upgrade 2	Underfloor air systems	New Const.	na	8.6	na	10.7	na	12.9
	Upgrade 3	Integrated Design Approach (IDA) to 25% below current construction	New Const.	na	0.0	na	0.0	na	0.0
	Upgrade 4	Integrated Design Approach (IDA) to 40% below current construction	New Const.	na	2.4	na	3.0	na	3.6

4.3 GENERAL LIGHTING—EXISTING AND NEW BUILDINGS

"General lighting" refers to lighting in the primary occupied areas of buildings. For example, this includes lighting in the main occupant areas of office buildings or retail stores or classroom lighting in schools. This general lighting is primarily fluorescent, but the current mix of technologies differs between existing and new buildings; consequently, each building vintage is discussed separately below.

4.3.1 Current Baseline Technologies—Existing Buildings

General lighting in existing commercial buildings is generally a mix of T12 lamps (ES) with energy-efficient magnetic ballasts and T8 lamps with either magnetic or electronic ballasts.[40] The target baseline technology for this analysis is the remaining stock of energy-saving (ES) T12 lamps and magnetic ballasts.

Two baseline annual hours of operation were assessed, 3,500 and 5,000, which represent the typical number of operating hours for offices and large retail buildings, respectively.

4.3.2 Energy Efficiency Upgrade Options[41]—Existing Buildings

Six energy efficiency upgrade options were identified for this end use. In increasing order of savings, they are as follows:

- Relamp and reballast with T8 Lighting Systems
- Relamp and reballast with Low Ballast Factor (BF) T8 Lighting Systems
- Redesign to "Next Generation" "Extreme System" T8 Lighting Systems
- Redesign to Lower-level Lighting (30 to 50 foot candles), plus T8 Lighting Systems
- Redesign to Lower-level Lighting (30 to 50 foot candles), plus "Next Generation" "Extreme System" T8 Lighting Systems
- Install Advanced, Fully Integrated Lighting Controls (e.g., "Ergolight or Lutron's PERsonna")

Each of these options is briefly described below. (For detailed cost and performance data *see* Appendix F.)

❑ **Relamp and reballast with T8 Lighting Systems**

Relamping and reballasting of existing T12 lamps (ES) and ballasts with T8 lamps and electronic ballasts reduces the connected lighting load for a two-lamp fixture from 72 watts to 59 watts, which represents a savings of 18% over the baseline for existing buildings.

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[40] A small population of T12 lamps and electronic ballasts is also present in the existing stock.

[41] The performance of lighting efficiency upgrade options used in the CCE calculations has been adjusted to account for interactive effects with cooling and heating loads. Adjustment values were determined based on a sample of electricity use simulation runs using the project's CEEAM model.

☐ Relamp and reballast with Low Ballast Factor T8 Lighting Systems

The addition of electronic ballast with a low ballast factor (BF) further reduces the connected lighting load to 51 watts per fixture, which represents a savings of 29% over the baseline for existing buildings.

☐ Redesign to "Next Generation" T8 Systems

High-performance "next generation" T8 systems are now available that operate with an efficacy of 100 lumens/W and have a longer lamp life than standard instant-start T8 systems.[42] For example, Sylvania's "Xtreme" system, with two high-performance T8 lamps, consumes 49 W/fixture, which represents a savings of 32% over the baseline, while providing the same light output.[43] General Electric (GE) also manufacturers a similar high-performance T8 system called the "Watt-Miser® Ultra XL." "Next generation" T8 systems can replace all current T8 systems.

☐ Redesign to Lower Level Lighting plus T8 Lighting Systems

Many office buildings continue to be overlit, with lighting levels of 50 to 70 foot candles compared to the recommended IES light levels for general reading range of from 30 to 50 foot candles.[44] By combining the redesigned (lower) light levels (30 to 50 foot candles) with the standard T8 lighting system, a savings of 59% over the baseline can be achieved in existing buildings. This estimate is based on a reduction in the lighting power density (LPD) from 1.7 to 0.7 W/sq.ft.

☐ Redesign to Lower Level Lighting plus "Next Generation" "Extreme System" T8 Lighting Systems

Inclusion of "next generation" T8 lighting with redesigned lighting (for the lower light levels of 30 to 50 foot candles) can increase savings to 65% over the baseline for existing buildings with a resulting LPD of 0.6 W/sq.ft.

☐ Install Advanced, Fully Integrated Lighting Controls

Advanced, fully integrated lighting controls combine several integrated electricity savings functions. For example, integrated lighting systems can be controlled to provide user-specified light levels and occupancy sensing, and they can respond to daylight sensing by dimming the lights. They can also be controlled from a central computer to adjust lighting levels in response to changing work patterns or to provide load relief when the electrical grid is demand constrained.

The Ergolight system, manufactured by Ledalite Architectural Products Inc., and Lutron's PERSonna are two commercially available examples of this type of system. The

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[42] For example, Sylvania reports that its FO32 Ecologic lamps have a rated life of 30,000 hr.

[43] *Sylvania Xtreme System: High Performance, Electricity Saving, Electronic T8 System*, Sylvania, Product Information Bulletin SYL001.

[44] The Building Check-Up database used to develop the office electricity use profiles assumes an LPD of 1.8 W/sq.ft., suggesting high light levels.

Ergolight system replaces existing lighting with T-8 fixtures centred above each work cubicle. The Ergolight system is a direct–indirect lighting system, where one lamp reflects from the ceiling while another two illuminate the work surface. An occupancy sensor controls the down-lamps to reduce their operating hours when an office is vacant. The operation of these down-lamps is also controlled by daylight sensors. Using a networked computer, individuals can adjust the light levels in their cubicle. A designated lighting manager can also control all the lighting by computer. Finally, an integrated lighting control system can form part of a building automation system with global scheduling that turns lights off during those hours when the office is unoccupied.

Integrated lighting control[45] systems can achieve savings of 70% over the baseline for existing buildings, with LPDs in the range of 0.5 W/sq.ft.[46] However, these systems apply primarily to office buildings.

4.3.3 Current Baseline Technology—New Buildings

The baseline technology for general lighting in new buildings is the standard T8 lamp with electronic ballast. Lighting levels are assumed to be 50 foot candles and fixture density at 64 sq. ft. per fixture. This results in a connected lighting load of 0.9 W/sq.ft.

4.3.4 Energy Efficiency Upgrade Options—New Buildings

Three energy efficiency upgrade options were identified for this end use. They are as follows:

- Redesign with "Next Generation" "Extreme System" T8 lighting Systems
- Redesign lighting to lower light levels (30 to 50 foot candles), plus "Next Generation" "Extreme System" T8 lighting system
- Installation of Advanced Fully Integrated Lighting Controls (e.g. "Ergolight")

☐ "Next Generation" "Extreme System" T8 Lighting System

This is the same system as described previously for existing buildings. However, due to the more efficient baseline technology in the new buildings, the average savings is 10 W per fixture relative to the baseline.

☐ Redesign to Lower Lighting Levels (30 to 50 foot candles), plus "Next Generation" T8 Lighting Systems

This is the same system as described previously for existing buildings. However, due to the more efficient baseline technology in the new buildings, average savings of 33% can be achieved, resulting in an LPD of 0.6 W/sq.ft.

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[45] The study assumes that other control technologies such as occupancy sensors are part of integrated lighting controls for the office segment. Other controls to schedule lighting are assumed to be part of the 2nd generation building automation systems that are addressed in subsection 4.7.

[46] This is based on monitoring data from a BC Hydro demonstration project.

☐ **Install Advanced, Fully Integrated Lighting Controls**

This is the same system as described previously for existing buildings. However, due to the more efficient baseline technology in new buildings, average savings of 46% can be achieved.

4.4 ARCHITECTURAL LIGHTING

"Architectural lighting" refers to the lighting in areas such as lobbies, foyers, corridors, washrooms and stairways, including exit signs. Compared to general lighting, architectural lighting typically differs in layout, has lower light levels and makes more use of accent/decorative lighting. Architectural lighting is primarily provided by incandescent lamps and CFLs.

4.4.1 Current Baseline Technologies

The baseline technology is the incandescent "A" lamp and the PAR lamp, with two lamp wattages being included: 75 W and 90 W. The baseline exit sign that is included in this end use is assumed to be incandescent and to draw 30 W.[47]

4.4.2 Energy Efficiency Upgrade Options

Three energy efficiency upgrade options were identified for this end use. They are:

- Replace 75-W or 90-W Par Lamps with CFLs (20 W or 26 W)
- Replace 75-W PAR Lamp with Light-Emitting Diodes (LEDs), (40-W equivalent)
- Replace a 30-W Exit Sign with a LED Exit Sign (4 W).

A brief description of each is provided below. (For detailed cost and performance data *see* Appendix F.)

☐ **Replace 75-W or 90-W Par Lamps with CFLs (20 W or 26 W)**

A generic 20-W CFL with a light output of 1,100 to 1,200 lumens can replace a 75-W or 90-W incandescent "A" lamp with a light output of 750 to 900 lumens. A 26-W CFL with a light output of 1,500 to 1,800 lumens can replace a 90-W PAR lamp with a light output of 1,300 lumens. A 20-W CFL with a 2-W ballast provides electricity savings of 70% over the baseline. A 26-W CFL with 4-W ballast provides electricity savings of 66% over the baseline incandescent PAR lamp. In addition to providing electricity savings, the CFLs have a long life of 10,000 hours. The generic CFLs are available as self-ballasted, screw-base (CFQ) and Quad lamps.

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[47] Although LED exit signs have captured a large share of the new sales market, they represent a small share of the existing market. See: "*Improved LEDs Set for Exit Sign Market,*" *E Source E News* (September 1998).

❑ **Replace 75-W PAR Lamp with Light-Emitting Diodes (LEDs) (40-W equivalent)**

White LEDs for task and accent lighting will be available within 2 to 3 years, and these will achieve efficacies of 20 to 30 lumens/W[48] and lives of 10,000 to 100,000 hours. Currently, white LED technology features a shorter life than red LEDs and higher lumen depreciation.[49, 50] However, efficacies continue to increase rapidly, and one manufacturer (Nichia) has achieved efficacies of 55 lumens/W in the laboratory. Annual savings from white LED task and accent lighting are estimated at 47%, based on an efficacy of 20 lumens/W.

❑ **Replace 30-W Incandescent Exit Sign with a LED Exit Sign (4 W)**

A 4-W LED exit sign can replace an existing incandescent exit sign that typically has two 15-W bulbs. The LED exit sign provides electricity savings of 87% over the baseline technology. In addition, LED lights have a life of 100,000 hours compared to the shorter life of incandescent lamps; this provides additional benefits in the form of lower maintenance and lamp replacement costs.

4.5 HIGH-BAY LIGHTING

"High-bay lighting" refers to lighting in large, high-ceilinged areas, such as gymnasiums and warehouses.

4.5.1 Current Baseline Technologies

The assumed baseline technology for this lighting application is a 400-W metal-halide fixture.

4.5.2 Energy Efficiency Upgrade Options

Two energy efficiency upgrade options were identified for this end use. In increasing order of savings, they are:

- Pulse-start Metal-halide Lamps
- High-intensity Fluorescent Lamps.

Each of these options is briefly described below. (For detailed cost and performance data *see* Appendix F.)

❑ **Pulse-start Metal-halide**

Pulse-start metal-halide lamps have been optimized for efficiency. Some lamps are designed for use with standard metal-halide ballasts, and they are therefore direct retrofits, but higher efficiencies are possible with improved ballasts.

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[48] "LEDs in Exterior Applications: An Emerging Market," *E Source E News* (November 2001)

[49] "What is the Useful Life of White LEDs," Lighting Research Centre

[50] "White LED Life Shorter," *Electrolink Magazine*, www.electrolink.co.nz

Electricity savings estimates depend on ballast type.[51] For example, the Sylvania Metalarc Supersaver, which uses a standard ballast, achieves savings of approximately 10 to 12%[52] over the standard metal-halide lamp (360-W versus a standard 400-W lamp). These lamps are available in a variety of sizes from several manufacturers. In addition to the electricity savings, other benefits include longer life (estimated lengths vary), better colour, faster warm-up time, less lumen depreciation over time and improved performance at cold temperatures.

Pulse-start metal-halide systems can be used in all current metal-halide applications. Electricity savings of 11% over the baseline system can be achieved.

- ☐ **High-Intensity Fluorescent (HIF)**

HIF lamp systems use bi-axial or linear T5 lamps, as well as bi-axial T8 lamps and induction lamps. HIF systems, such as Sylvania's Icetron 157-W lamp, can replace traditional metal-halide (HID) fixtures in many high-bay lighting applications. The HIF system provides efficacies of 100 lumens/W compared to 60 to 80 lumens/W for a standard 400-W metal-halide fixture. Combined with the higher colour rendition of the HIF lamps, electricity savings of 45 to 50% can be achieved over conventional metal-halide lighting.

Other benefits over traditional instant-start metal-halide lamps include shorter restrike times, better colour, better dimming options, better light quality and better light output maintenance over time.[53]

Currently, there are some application limitations. For example, these lights are not suitable for use in cold weather or for very high ceilings or flood light applications. The technology is very new; consequently, there is limited availability of some fixture types that are suitable for replacing HID lamps up to 400 W. In addition, high-intensity fluorescent lamps have a rated lifetime of about 15,000 hours. This is slightly shorter than that of a typical metal-halide lamp (20,000 hours); however, metal-halide lamps are often replaced early because of the lumen depreciation associated with them.

Annual electricity savings resulting from use of an HIF are 48% relative to the baseline metal-halide system.

4.6 BUILDING ENVELOPE

"Building envelope" measures improve the thermal performance of the building's walls, roof or windows.

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[51] "Pulse-Start Metal Halide Lamps Fact Sheet (1999)," (online) Electricity Center of Wisconsin, http://www.ecw.org/prod/metalhal.pdf (16 July 2002)

[52] *Product Information Bulletin (2001): Metalarc Supersaver, Electricity Saving Replacement Metal Halide Lamps*, Osram Syvania, Westfield Indiana

[53] "New High-Intensity Fluorescent Lights Outshine Their HID Competitors," *E Source E News* (January 2000)

4.6.1 Current Baseline Technologies

The baseline for new buildings is assumed to be a thermal resistance of R8 for the walls and double pane windows with an overall U value of 0.5 to 0.55 Btu/hr./(sq.ft: °F).

4.6.2 Energy Efficiency Upgrade Options

Three energy efficiency upgrade options were identified for this end use. They are:

- Gas-filled Wall Panels (GFP)
- Vacuum Panel Insulation (VPI)
- High-performance Windows.

Each of these options is briefly described below. (For detailed cost and performance data *see* Appendix F.)

❑ Gas-filled Wall Panels

Gas-filled Wall Panels (GFP) are to conventional fibreglass insulation what double pane windows are to single pane glazing. They represent a significant difference in performance. GFPs are sealed bags encased in a honeycombed baffle, with the entire panel filled with a low-conducting gas, such as argon or krypton. GFPs can attain thermal performances of R7/in. of wall thickness with argon gas filling and R12.5/in. with krypton gas filling.

Using this technology, a higher insulation performance of R20 can be attained with no increase in the wall thickness. Energy savings of 20% in space heating have been calculated through the modelling of commercial buildings with heating energy intensities of 3 to 5 kWh/sq.ft./yr.

❑ Vacuum Panel Insulation

Vacuum Panel Insulation (VPI) can achieve thermal resistance levels that are three to seven times those provided by conventional insulation materials, such as rigid foam boards and fibreglass. The technology consists of a core panel enclosed in an airtight, vacuum-sealed envelope. Such panels can attain thermal resistances of approximately R20/in. Although targeted primarily to refrigerators and specialized containers, VPI can be manufactured in any size and is thus a suitable product for buildings.

A wall component with a thermal resistance of R40 can achieve energy savings of 25 to 30% in space heating. This is based on modelling results for buildings having heating intensities of 3 to 5 kWh/sq.ft./yr.

❑ High-Performance Windows

A whole window unit having a thermal resistance greater than R4 can be achieved with triple-pane windows or with double-pane windows that have two suspended low-emissivity (low-e) films. The advantage of low-e films is that they improve thermal performance without adding significant weight. High-performance, double-pane windows that achieve thermal resistance values as high as R7 are currently available[54, 55] from several companies, including "Visionwall" from Visionwall Corporation and "Superglass" from Southwall Technologies.

Energy savings of 40% in space heating have been calculated through modelling of commercial buildings with an assumed window to wall ratio of 50% and heating energy intensities of 3 to 5 kWh/sq.ft./yr. Energy savings are reduced to 30% in a building with a window to wall ratio of 30%.

4.7 HEATING, VENTILATING AND AIR-CONDITIONING EQUIPMENT (HVAC)

"HVAC equipment" includes fans and pumps used to distribute conditioned air and water throughout a building, as well as the pumps and fans incorporated into auxiliary equipment, such as cooling towers. The controls that govern the operation of fans and pumps also govern their energy use and their operating parameters (design flows and pressures) and maintenance.

4.7.1 Current Baseline Technologies

The majority of large commercial buildings have Building Automation Systems/Facilities Management Systems (BAS/FMS) that were installed during construction or added at a later date. However, only a small proportion of the systems will have been maintained on a continuous basis by modifying the control sequences/software routines. Similarly, few will have had their software revised or the control algorithms updated. BAS/FMS baseline technology is therefore assumed to be a system that is operating on a degraded mode with a number of bypassed control routines.[56]

4.7.2 Energy Efficiency Upgrade Options

There are three general strategies for achieving HVAC energy savings. They are:

- Improve HVAC system control through better use of BAS/FMS systems;
- Optimize system operating parameters through air and water rebalancing; and
- Adopt improved maintenance procedures, for example, through regular adjusting or replacing of belts to reduce slippage.

These strategies apply primarily to larger commercial buildings. In general, large commercial buildings have more complex HVAC equipment, which is able to take advantage of BAS/FMS controls, and these require continuous maintenance. Medium-sized and small commercial buildings that rely on packaged HVAC equipment offer less of an opportunity for use of BAS/FMS controls or improved maintenance.

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[54] "Superglass Quad"(online), Southwall Technologies, http://www.southwall.com/products/superglass.html (23 July 2002)

[55] "4 Element Performance Data" (online), Visionwall Corporation, http://www.visionwall.com/productsservicesrange.htm#Anchor-47857 (23 July 2002)

[56] This supposition is supported by selected hourly load profiles of three large office buildings, which show that much of the equipment remains on during unoccupied hours, and electricity use is 30 to 50% that of the peak daytime load.

The following HVAC efficiency upgrades were assessed for this end use:

- Recommissioning
- "Next Generation" Building Automation Systems/Facilities Management Systems (BAS/FMS)
- Variable-speed Fans and Pumps.

Each of these options is briefly described below. (For detailed cost and performance data *see* Appendix F.)

❑ Recommissioning

"Recommissioning" is a process of optimizing the operation of existing buildings through low-cost/no-cost repairs and operational changes.[57] It includes the following tasks:

- Optimize system operations to improve comfort and reduce energy costs;
- Solve existing comfort or indoor air quality problems;
- Undertake air and water rebalancing;
- Review and update equipment control sequences to ensure optimum operation during occupied periods and shutdown during unoccupied periods;
- Ensure ongoing optimal operation through involvement and training of building staff; and
- Make recommendations for system improvements and retrofits.

In contrast to the conventional audit and retrofit process, recommissioning involves a greater investment in monitoring and simulation of building systems to gain a thorough understanding of current operation and possibilities for optimization. Because the measures recommended tend to be inexpensive, the overall cost is typically one-third that of the audit/retrofit process. Overall costs range from $0.40 to $0.80/sq.ft., most of which represents the cost of labour.

Energy savings of 25% typically result from recommissioning, and these come mostly from repairs to equipment, such as valves, controllers or thermostats, and from optimization of duct pressures, hot and cold air temperatures, variable air volume settings and pump control. Paybacks are typically achieved over 1 to 2 years.

Because of the significant initial investment in monitoring and simulation, this approach is most suitable for commercial buildings with over 50,000 sq. ft. in floor area.

❑ "Next Generation" Building Automation Systems/Facility Management Systems (BAS/FMS)

The latest generation of BAS/FMS is able to automatically detect anomalies in building operations and can automate building diagnostics as well. These systems typically take data on how energy systems are performing in a building, analyze them using logic and physical modelling to detect deviations from expected performance and use built-in logic to suggest the cause of the deviation.[58]

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[57] Marbek, "Recommissioning Options Discussion Paper," prepared for Public Works and Government Services Canada, March 200

In addition, the newer generations of BAS/FMS have improved predictive, self-tuning control algorithms that help to minimize the need for by-pass or override of the BAS/FMS.

Energy savings of 5 to 20% can be achieved from the installation of a "next generation" BAS/FMS or from a system upgrade that incorporates new front-end, automated diagnostics and control strategies. These savings result from re-instituting equipment scheduling, expanding control strategies (lighting) and improving self-tuning control strategies.

☐ **Variable Speed Pumps**

Typical chilled water pumps in commercial buildings can be retrofitted with variable-speed drives with resulting energy savings of 20 to 50% of baseline pumping electricity use. Some applications cannot be economically converted, however, as variable-speed pumping requires the use of two-way valves on cooling coils. Conversions usually require the replacement of three-way valves and the addition of control points to the existing BAS/FMS and variable-speed drives.

4.8 HEATING EQUIPMENT

"Heating equipment" refers to electric space heating technologies that include electric resistance air source heat pumps (ASHPs) and water loop heat pumps (WLHPs). Both technologies are achieving small performance improvements; however, ASHPs have the greater potential for substantial gains in performance. In the commercial sector, ASHPs are most commonly found in low-rise buildings that use packaged rooftop units and in hotels that use packaged terminal heat pumps (PTHPs).

4.8.1 Current Baseline Technologies

The baseline technology is an ASHP mounted on a rooftop heating-cooling unit or configured as a PTHP. A seasonal COP of 1.5 is assumed for the baseline system.

4.8.2 Energy Efficiency Upgrade Options

One heating equipment upgrade was assessed for this end use:

- Cold-climate Heat Pumps

This option is briefly described below. (For detailed cost and performance data *see* Appendix F.)

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[58] "Automated Building Diagnostics: Improving Electricity Performance and Occupant Comfort," *E Source E News*, ER-01 (18 Nov 2001).

❑ Cold-Climate Heat Pumps

Cold-climate heat pumps are air-to-air heat pumps that have been optimized for colder climates. The performance of these heat pumps is expected to be approximately the same as ground-source heat pumps (GSHP). Residential-sized units are currently available and are being field-tested. Large commercial units (5 to 12 tons) are expected to be available in the near future.[59]

The life span of cold-climate heat pumps is expected to be 20 to 22 years.[60] The cost is approximately equivalent to that of a GSHP, minus the cost of the ground-loop,[61] or $800 to $1,000 more than a conventional high-efficiency air-to-air heat pump.[62] Heating efficiencies are expected to be 10 to 15% less than GSHPs;[63] this is equivalent to a COP of close to 3 in the northern U.S. and southern Canada.[64] For cooling, a seasonal electrical efficiency rating (SEER) of 16 is expected.[65]

4.9 COOLING EQUIPMENT

"Electric cooling" equipment for large commercial buildings refers to large-tonnage reciprocating and centrifugal chillers. These units are assumed to be water-cooled and to use a cooling tower.

4.9.1 Current Baseline Technologies

The baseline technology is assumed to be a centrifugal chiller with a performance of 0.58 kW/ton.[66] This is also the assumed performance of a new replacement chiller.

4.9.2 Energy Efficiency Upgrade Options

This option is briefly described below. (For cost and performance data *see* Appendix F.)

❑ High-Efficiency Air-Conditioning (Chiller Upgrade)

High-efficiency centrifugal chillers with a full load performance of 0.5 to 0.58 kW/ton and lower integrated part load values (IPLV) of 0.45 to 0.55 kW/ton are available from all the large manufacturers. A performance target of 0.5 kW/ton was assumed for large commercial buildings, which results in 14% electricity savings over the performance of the baseline new replacement chiller.

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[59] Telephone interview with Geoffrey Clarke, General Manager of Nyle Corporation, August, 2002.

[60] Clarke

[61] Clarke

[62] *E Source E News*, (May 22, 2002)

[63] Clarke

[64] "Nyle Corp. Unveils New Cold Climate Heat Pump," *Cutter Edge Buildings* (weekly e-mail service), Cutter Edge Information Corp (23 October 2001)

[65] *E Source E News*, op. cit.

[66] The minimum performance level for a water-cooled centrifugal chiller in the ASHRAE Standard 90.1-2001 is 0.58kW/ton, with an IPLV of 0.55 kW/ton.

4.10 FOOD REFRIGERATION

"Food refrigeration" refers to the energy used to refrigerate food in supermarket display cases. The technology covers medium- and low-temperature (frozen food) refrigeration applications. The energy use for food refrigeration includes compressors and condensers, as well as the additional energy used for display cases, including defrosting.

4.10.1 Current Baseline Technologies

The target baseline technology for this end use is the remaining stock of single, dedicated fixed-demand compressors. Although multiplexed compressors have captured a significant market share, especially in large and newer supermarkets,[67] a large share continues to be occupied by the baseline technology. Similarly, many open refrigerated display cases continue to exist in the market, despite a general industry move towards closed display cases.

4.10.2 Energy Efficiency Upgrade Options

Four energy efficiency upgrade options were identified for this end use. In increasing order of savings, they are:

- Unequal-demand Multiplexed Compressor
- Door/Cover Upgrade
- Floating Head Pressure Control
- Smart Defrost Control.

Each of these options is briefly described below. (For detailed cost and performance data *see* Appendix F.)

☐ Unequal-demand Multiplexed Compressor

Unequal-demand multiplexed compressors employ multiple compressors interconnected with common suction and discharge lines to serve a group of display cases. This arrangement provides electricity savings of 25% over single-compressor systems.

☐ Door/Cover Upgrade

Doors and covers for display cases can provide refrigeration electricity savings of 20 to 30% over open display cases. A typical store would achieve an overall 10% savings in refrigeration electricity use.[68]

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[67] *Technology and Current Electricity Trends in Supermarkets*, EPRI 2000

[68] *The State of the Art: Appliances*, Competitek (1990), p. 164

- ☐ **Floating Head Pressure Control**

This technology allows more heat to be rejected through the condenser at low outside air temperatures, thereby increasing the compressor efficiency. The resulting electricity savings are in the range of 10 to 20%.[69,70]

- ☐ **Smart Defrost Control**

Efforts are underway to reduce the energy use from defrost cycles through "Smart" sensorless defrost controllers. The technology was being tested in 2000 and had reduced defrost cycles by 65% with an equivalent reduction in compressor electricity of 15%.[71]

4.11 DOMESTIC HOT WATER

Domestic Hot Water (DHW) is used in commercial buildings for hand-washing and shower services, cleaning and food preparation. The proportion of the DHW load that is specifically used for "hand-washing and shower services" can be reduced in flow.

4.11.1 Current Baseline Technologies

Older shower heads used in commercial applications have flow rates of 2.5 to 4 gallons per minute (gpm). Typical faucets have flow rates of 2 to 4 gpm.

4.11.2 Energy Efficiency Upgrade Options

Two energy efficiency upgrade options were identified for this end use. They are:

- Faucet Aerator and Self-Closing Faucet
- Low-Flow Shower Head.

These options are briefly described below. (For detailed cost and performance data *see* Appendix F.)

- ☐ **Faucet Aerator**

Faucet aerators, by mixing water and air, lower the water flow from between 2 to 4 gpm to less than 1 gpm. The faucet aerator creates a fine water spray with a screen that is inserted in the faucet head. A further refinement is the addition of self-closing taps that shut-off automatically after a specified time.

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[69] Ibid.

[70] BC Hydro demonstration projects.

[71] *Technology and Current Electricity Trends in Supermarkets*, EPRI 2000.

- ☐ **Low-flow Shower Head**

Low-flow shower heads use the same principle as faucet aerators to achieve a flow reduction of 30 to 50%, which in turn lowers the flow rate to somewhere between 1.5 to 2.2 gpm.

4.12 OFFICE EQUIPMENT

"Office equipment" refers to desktop computers and monitors present in offices and other segments of the commercial building stock that have a high density of computers per occupant.

4.12.1 Current Baseline Technologies

The baseline technology is assumed to be computers with no reduced standby power features or with the feature not enabled.[72]

4.12.2 Energy Efficiency Upgrade Options

One energy efficiency upgrade option was assessed for this end use.

- ☐ **Energy Star Equipment**

This option is briefly described below. (For detailed cost and performance data *see* Appendix F.)

- ☐ **Energy Star Equipment**

Energy Star office equipment uses less energy than standard office equipment, in part because it automatically goes into a "sleep" state after a specified period of inactivity. Several studies suggest that this more efficient equipment has the potential to reduce office equipment energy use by a third.[73, 74] However, actual savings may be less because users often fail to enable the Energy Star capabilities of their equipment.

4.13 NEW BUILDING DESIGN

"New building design" technologies include an integrated design approach to achieve more efficient construction and the introduction of alternative HVAC designs, such as under-floor air systems and low temperature distribution.

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[72] Hourly load profiles for three office buildings show high after-hours electricity use. Part of this high electricity use is attributed to desktop computers that do not switch to stand-by or sleep mode when inactive.

[73] "Efficient Computers and Office Equipment" (online), Rocky Mountain Institute, http://www.rmi.org/sitepages/pid300.php (26 July 2002).

[74] Floyd, D.B. and D.S. Parker, (1996) "Measured Performance of Electricity-Efficient Computer Systems," (online) Florida Solar Electricity Center, http://www.fsec.ucf.edu/~bdac/pubs/PF303/PF303.html (26 July 2002).

4.13.1 Current Baseline New Construction

Baseline new construction is assumed to follow the MNECB/ASHRAE 90.1 standards. Current construction practices for some segments, such as office buildings, are assumed to surpass the standards by 5 to 10% in terms of energy savings.

4.13.2 Energy Efficiency Upgrade Options

Four energy efficiency upgrade options were identified for this end use. In increasing order of savings, they are:

- Low Temperature Distribution (LTD) and Thermal Energy Storage (TES)
- Under-floor Air System
- Integrated Design (to 25% below current construction)
- Integrated Design (to 40% below current construction).

Each option is briefly described below. (For detailed cost and performance data *see* Appendix F.)

☐ Low Temperature Distribution (LTD)

Low Temperature Distribution (LTD) designs use lower supply air temperatures, which results in lower volumes of air being distributed throughout the building. The energy savings are based on a 50% reduction in fan electricity use and a reduction in pump electricity use. The resulting overall reduction in energy used by HVAC equipment is estimated to be 1.5 kWh/sq.ft./yr.[75]

☐ Under-floor Air System

Under-floor air systems provide lower volumes of air to the space with a consequent reduction in fan electricity use. The air is also introduced into the space at higher air temperatures, which increases the chiller efficiencies. HVAC savings are estimated to be in the range of 15 to 30% due to reduced fan and chiller electricity use.

☐ Integrated Design (to 25% below current construction)

The Integrated Design Approach (IDA) is predicated on a systematic application of energy measures to all end uses at the design stage. This includes targeting the building envelope, lighting, HVAC equipment (fans and pumps) and, finally, the heating and cooling plants. To date, BC Hydro's Design Assistance Program has achieved savings of about 2 kWh/sq.ft./yr. over current practice.[76]

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[75] *New Directions in HVAC Systems*. Electricity Engineering (1994).

[76] Source: Graham Henderson, BC Hydro.

- **Integrated Design (to 40% below current construction)**

This level of savings assumes a much higher hurdle rate that will require a very high-performance design, equivalent to C-2000 levels. This requires a full IDA that takes advantage of costs trade-offs from equipment downsizing. The design will require the most energy-efficient technologies, extremely efficient lighting designs (which include daylighting features) and heating/cooling plants with very high part-load efficiencies. The energy savings of 40% are equivalent to a reduction of 8 kWh/sq.ft./yr.

5. ECONOMIC POTENTIAL FORECAST

5.1 INTRODUCTION

This section presents the Commercial Sector Economic Potential Forecast for the study period (FYs 2000/01 to 2015/16). The Economic Potential Forecast estimates the level of electricity consumption that would occur if all equipment and building envelopes were upgraded to the level that is cost effective against the long-run avoided cost of electricity in the BC Hydro service region. In this study, cost effective means that the technology upgrade cost, referred to as the Cost of Conserved Energy (CCE),[77] is equal to, or less than, the avoided cost of new electricity supply delivered to the Lower Mainland, which for this study is $0.06/kWh.[78]

The discussion in this section is organized according to the following subsections:

- Avoided Cost Used for Screening
- Major Modelling Tasks
- Technologies Included in Economic Potential Forecast
- Presentation of Results
- Interpretation of Results.

5.2 AVOIDED COST USED FOR SCREENING

BC Hydro Energy Planning recommended that the Conservation Potential Review team use a "levelized" cost of $0.06/kWh to assess which measures to promote customer efficiency (Demand-Side Management or DSM measures) are economic. When the 1991/94 Review was conducted, the avoided cost—or long-run marginal cost—was based on the cost of new large hydroelectric facilities. Today, planners expect the long-run marginal cost to be based on the cost of new, efficient, gas-fired Combined Cycle Gas Turbines (CCGT). The cost of CCGT supply per unit of electricity is significantly determined by the long-run marginal cost of natural gas. Current estimates are that the cost of new CCGT supply, is $0.055/kWh at the Lower Mainland load centre. However, $0.06/kWh was recommended for use in the CPR 2002 to allow a slightly more liberal screening of DSM measures for further assessment. BC Hydro does not consider the costs associated with a particular project, designed to meet specific needs, to be useful in screening categories of possible DSM measures in this Review. Using $0.06/kWh gives BC Hydro's Power Smart program planners a more robust set of data to work with as they go through the process of bundling measures into Power Smart programs. Using $0.06/kWh also ensures that the results of this study have a good "shelf life" for Power Smart program and resource planning purposes.

The Economic Potential Forecast incorporates all the electric energy-efficient upgrades that the technology assessment found with a CCE equal to or less than $0.06/kWh. The BC Hydro Core team then reviewed the CCE results to ensure that no technology of consequence was being excluded by the six cents cut-off. They found no significant technologies had been excluded.

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[77] At a discount rate of 8%.

[78] Value provided by BC Hydro.

5.3 MAJOR MODELLING TASKS

By comparing the results of the Commercial Sector Economic Potential Forecast with the Reference Case, it is possible to determine the aggregate level of potential electricity savings within the Commercial Sector and to identify which specific building segments and end uses provide the most significant opportunities for savings. To develop the Commercial Sector Economic Potential Forecast, the following steps were undertaken:

- The CCEs for each of the electrical efficiency upgrades presented in Exhibit 4.1 were reviewed, using the 8% discount rate.[79]
- Technology upgrades that had CCEs equal to, or less than, the $0.06/kWh threshold were selected for inclusion in the economic potential scenario, either on a "full cost" or "incremental" basis. It is assumed that technical upgrades having a "full cost" CCE that met the cost threshold were implemented in the first forecast year. It is assumed that those upgrades that only met the cost threshold on an "incremental" basis are being introduced more slowly as the existing stock reaches the end of its useful life.
- Electricity use within each of the building segments was modelled with the same energy models used to generate the Reference Case. However, for this forecast, the remaining "baseline" technologies included in the Reference Case forecast, were replaced with the most efficient "technology upgrade option" and associated performance efficiency that met the cost threshold of $0.06/kWh.

5.4 TECHNOLOGIES INCLUDED IN ECONOMIC POTENTIAL FORECAST

The technologies that were included in the Economic Potential Forecast differed by building segment, depending on their applicability to the specific segment. For example, integrated lighting control systems, such as the Ergolight System, were assumed to be tailored to office workstations and therefore applicable only to the office segment. Similarly, it was assumed that lighting redesign to lower design levels did not apply to the food and non-food retail segments, as light levels are critical to those types of retail sales. In cases where light levels could not be reduced, the measure selected was a simple conversion to the second generation T8 fluorescent system.

Exhibit 5.1 shows a generic list of the measures selected for inclusion in the Economic Potential Forecast. Further detail is also provided below, organized by building segment.

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[79] The term CCE that is used in this study refers to the same methodology as was used in the original CPR. However, in the original CPR, the term Total Resource Cost (TRC) was used. In both CPRs program and administrative costs were excluded. Since the TRC normally includes program and administrative costs, it was considered clearer to use the term Cost of Conserved Energy in this effort. Adding 0.5 to 1.0 cent per kilowatt hour to the CCE used in this review would give a rough approximation of the TRC as it is usually calculated.

Exhibit 5.1: Generic Listing of Technologies Included in Economic Potential Forecast

End Use	Type of Measure
General Lighting	• Second-generation T8 Lighting System • Lighting Redesign (to 30 foot candles, offices, schools and university colleges) • Integrated Lighting Controls (Ergolight or PerSONNA, office buildings only)
Architectural Lighting	• CFLs • White LED
High-bay Lighting	• High-intensity Fluorescents (HIF)
Office Equipment	• Energy Star (reduced standby power computer and flat screen monitors)
Space Heating (Electric)	• Advanced Cold Climate Heat Pump
Space Cooling	• HE Large-tonnage chillers
HVAC Equipment	• Recommissioning—office, large retail, university/colleges • Second-generation BAS/FMS
New Construction	• Integrated Design (to 40%)

☐ Large and Medium Office—Existing

The most significant electricity savings upgrades in these building segments included:

- Lighting redesign to 30 foot candles (fc) was assumed with a fully integrated lighting control system, such as "Ergolight" or Lutron's "PerSONNA".
- Lighting power densities (LPDs) were reduced from an existing 1.75 W/sq.ft. to 0.7 W/sq.ft. Shutdown during unoccupied hours was also assumed.
- CFLs or white LED systems replaced incandescent lighting used for accent and architectural lighting in lobbies, atriums and hallways.
- Savings in plug loads were assumed from the replacement of existing CRTs (75 W per monitor) with flat screen panels (40 W per monitor), along with reduction in standby power during unoccupied hours (Energy Star-compliant computers).
- Recommissioning and second-generation BAS/FMS were applied; savings in HVAC equipment demand and energy use result from the combination of rebalancing, higher fan and pump efficiencies and reduced operating time during unoccupied hours.
- Non-CFC chillers with an energy performance of 0.5 kW/ton replaced the remaining CFC chillers with a 0.75-kW/ton performance.

☐ Large and Medium Food and Non-food Retail—Existing

In the large non-food and food retail segments, higher efficiency equipment replaced all lighting types. This was done as follows:

- Replacement of all fluorescent with second-generation T8 lighting (100 lumens/W).
- Replacement of most incandescent with CFLs and white LED, although a small percentage of incandescent lighting was assumed to remain for those applications requiring a white spotlight with high colour rendition.
- Replacement of metal-halide HID lighting with HIF lighting.
- Replacement of CFC chillers in large retail buildings with high-efficiency, non-CFC chillers that achieve an efficiency of 0.5 kW/ton.

☐ Large Hotels and Medium Hotel/Motel—Existing

The most significant electricity savings upgrades in these building segments included:

- Replacement of all fluorescent with second-generation T8 lighting (100 lumens/W).
- Replacement of most incandescent with CFLs and white LED, although a small percentage of incandescent was assumed to remain for applications that cannot be met with CFL technology.
- Replacement of standard PTACs in hotels with units that use the ACCHP cycle.

☐ Hospitals, University/ Colleges and Schools—Existing

The approach used in these building segments was similar to that applied to the office segments, except that no reduction in light levels was assumed. This included:

- Replacement of all fluorescent with second-generation T8 lighting (100 lumens/W)
- Replacement of all incandescent with CFLs and white LED
- Replacement of existing CFC chillers with HE non-CFC chillers (0.5 kW/ton)
- Implementation of recommissioning and second-generation BAS/FMS (limited applicability of recommissioning in schools).

☐ Other Remaining Segments—Existing

The measures applicable to the other remaining segments were principally aimed at replacing all lighting types with higher efficacy equipment. Other measures that were selected included ACCHP, where applicable, and efficient refrigeration technologies in the food retail segment.

☐ New Construction

An Integrated Design Approach (IDA) was applied to all new buildings. All the technologies applicable to existing buildings were used to achieve the lowest possible connected load and energy use in all end uses. IDA was modelled by systematically reducing the loads and by ensuring that equipment only operated when needed. More specifically, the approach was as follows:

- Minimize the building and lighting loads by using the best available lighting systems.
- Size the equipment to meet the reduced loads.
- Meet the reduced loads with the best available equipment.
- Provide optimum operating schedules with minimum operation during unoccupied hours.

Minimizing the lighting load and electricity use was achieved by the use of ideal light levels, use of technology with the highest efficacy and minimum hours of operation (only security lighting operates during the unoccupied period).

HVAC equipment was assumed to meet the loads precisely and to operate at its highest efficiency (backwards curved centrifugal fans and variable speed pumps).

☐ Summary

Exhibits 5.2 and 5.3 compare energy-use intensities (EUIs) for the whole building between the 2015 baseline and the economic potential for existing and new buildings, respectively. (In addition, *see* Appendix G, which compares EUIs within the existing building segments in the Reference Case and Economic Potential Forecast.)

Exhibit 5.2: Comparison of Whole Building EUIs for Existing Buildings

Building Segment	Existing Building 2015 kWh/sq.ft./yr.	Economic Potential kWh/sq.ft./yr.	% Reduction
Large Office	25.3	15.8	38
Medium Office	21.5	13.9	35
Large Non-food Retail	24.4	18.0	26
Medium Non-food Retail	22.5	18.4	18
Food Retail	60.7	51.4	15
Large Hotel	16.4	13.8	16
Medium Hotel/Motel	16.3	14.0	14
Hospital	18.1	15.7	13
Nursing Homes	14.9	12.9	13
Large School	8.5	7.5	12
Medium School	7.0	5.9	16
University/College	16.9	12.4	27
Restaurant/Tavern	35.9	33.1	8
Warehouse/Wholesale	14.4	13.6	6
Mixed Use	8.7	6.4	26

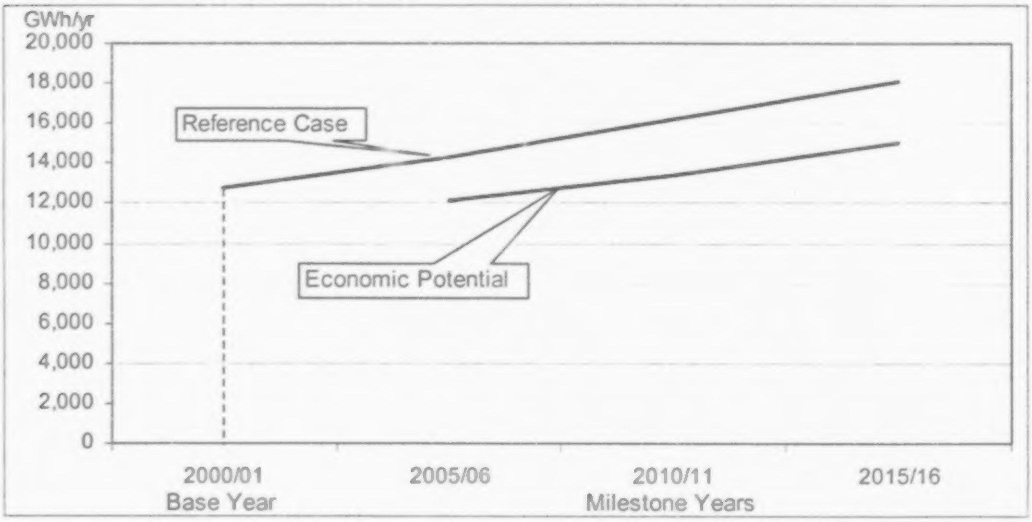
Exhibit 5.3: Comparison of Whole Building EUIs for New Buildings

Building Segment	New Building Baseline kWh/sq.ft./yr.	2015 New Building kWh/sq.ft./yr.	% Reduction
Large Office	18.8	12.9	31
Medium Office	18.0	11.4	37
Large Non-food Retail	22.5	15.3	32
Medium Non-food Retail	21.7	16.9	22
Food Retail	54.9	46.9	14
Large Hotel	14.4	12.2	16
Medium Hotel/Motel	13.9	11.3	19
Hospital	18.2	17.0	6
Nursing Homes	13.9	12.1	13
Large School	9.3	8.6	8
Medium School	7.1	6.5	9
University/College	13.3	10.3	23
Restaurant/Tavern	35.9	33.1	8
Warehouse/Wholesale	12.4	11.3	9
Mixed Use	8.7	6.4	26

5.5 PRESENTATION OF RESULTS

Exhibit 5.4 compares levels of commercial sector electricity consumption for the Reference Case and the Economic Potential Forecast. As illustrated, under the Reference Case, commercial electricity use would grow from base year levels of approximately 12,700 GWh/yr. to approximately 18,056 GWh/yr. by the FY 2015/16. This contrasts with the Economical Potential Forecast in which electricity use grows to 14,984 GWh/yr. over the same period, a reduction of approximately 3,072 GWh/yr.

Exhibit 5.4: Annual Electricity Consumption —Reference Case versus Economic Potential Forecast for the Commercial Sector, (GWh/yr.)



5.5.1 Electricity Savings

The following exhibits provide further detail on the total potential electricity savings within the Economic Potential Forecast:

- Exhibit 5.5 presents the results by service region and milestone year;
- Exhibit 5.6 presents the results by building segment and milestone year;
- Exhibit 5.7 presents the results by end use and milestone year; and
- Exhibit 5.8 provides a further disaggregation of the savings by end use, technology, milestone year and cost.

Exhibit 5.5: Annual Electricity Savings— Economic Potential versus Reference Case by Service Region and Milestone Year, (GWh/yr.)*

Milestone Year	Lower Mainland	Vancouver Island	Interior	Total	Savings (%) Relative to Reference Case
2005/06	1,481	326	352	2,159	15
2010/11	1,952	397	405	2,754	17
2015/16	2,190	438	444	3,072	17
Savings (%) Relative to Reference Case	18	16	15	17	

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 5.6: Annual Electricity Savings—Economic Potential versus Reference Case by Building Segment and Milestone Year, (GWh/yr.)*

Building Segment	Milestone Year			Savings in 2015/16 (%)	
	2005/06	2010/11	2015/16	Re Ref. Case	Re Total
Large Office	243	529	598	36	19
Medium Office	50	128	142	35	5
Large Non-food Retail	261	319	373	28	12
Medium Non-food Retail	56	68	79	20	3
Food Retail	65	73	82	15	3
Large Hotel	35	39	43	15	1
Medium Hotel/Motel	18	20	23	15	1
Hospital	35	38	41	11	1
Nursing Homes	6	7	8	14	<1
Large School	38	40	44	10	1
Medium School	25	26	28	13	1
University/College	132	140	149	26	5
Restaurant/Tavern	25	29	34	8	1
Warehouse/Wholesale	22	26	30	6	1
Mixed Use	11	11	11	18	<1
Small Commercial	700	765	828	12	27
Other Commercial Buildings	211	243	280	16	9
Other Non-buildings	227	251	277	15	9
Total	**2,159**	**2,754**	**3,072**	**17**	**100**

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 5.7: Annual Electricity Savings—Economic Potential versus Reference Case by End-use and Milestone Year, (GWh/yr.)*

End-use	Milestone Year			Savings in 2015/16 (%)	
	2005/06	2010/11	2015/16	Re Ref. Case	Re Total
General Lighting	1,167	1,578	1,687	31	55
Architectural Lighting	210	228	246	27	8
Other Lighting	15	16	17	18	1
Office Equip. and Plug Loads	25	59	104	6	3
Commercial Food Service	<1	<1	<1	<1	<1
Commercial Refrigeration	46	50	55	6	2
Miscellaneous (elevators, ext. lights)	0	0	0	0	0
Electric Space Heat	-9	-20	-32	-6	-1
Space Cooling	23	57	99	26	3
Electric DHW	3	3	3	2	<1
HVAC Equipment (fans, pumps)	243	290	337	14	11
Non-modelled Aggregate	438	494	557	15	18
Total	**2,159**	**2,754**	**3,072**	**17**	**100**

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 5.8: Potential Electricity Savings by End-use, Technology, Segment, Milestone Year and CCE*

End Use	Technology	Segment	Savings (GWh/yr.)			CCE @8% DR
			2005/06	2010/11	2015/16	(¢/kWh)
General Lighting	Lighting redesign, advanced T8 and Ergolight controls	Existing large and medium office	92	353	337	3.8 to 5.4
General Lighting	Advanced T8, and lighting redesign	Existing large commercial (except office)	410	405	397	3.0 to 5.4
General Lighting	Advanced T8, and lighting redesign	Existing and new small commercial	596	650	699	4.0 to 5.4
Architectural Lighting	Advanced T8, CFL's and White LED	All existing large commercial	136	135	133	2.9 to 5.5
Architectural Lighting	Advanced T8, CFL's and White LED	Existing and new small commercial	60	65	70	4.0 to 5.4
High-bay lighting	High-intensity fluorescents	Large retail, Large/medium schools and warehouse	28	28	28	3.5 to 5.0
High-bay lighting	High-intensity fluorescents	Existing and new small commercial	1	1	1	4.0 to 5.4
HVAC Equipment	Recommissioning, 2nd Gen BAS/FMS, VSD's	All existing large commercial	166	166	166	4.5 to 4.9
HVAC Equipment	2nd Gen. BAS/FMS	Existing and new small commercial	49	59	71	4.8
Space Heating	Advanced cold climate heatpump	Existing larege/medium hotel and nursing homes	0	1	1	4.4 to 5.6
Space Cooling	High efficiency chiller	Existing large/medium offices, large/medium retail, hosp	7	13	20	5.4
Commercial Refrigeration	Multiplexed compressors, display cases, head pressure control, smart controls	Existing Large food retail	42	42	42	2.7 to 5.9
Domestic hot water	Low flow devices	All existing large commercial	3	3	3	0.8
Plug loads and office equipme	Energy star compl;iant computers	Large/medium offices, hospitals and university/college	22	46	75	0
Whole Building	Integrated design approach	All new large commercial	106	285	457	2.4
Whole Building	Miscellaneous measures	Existing other commercial buildings	183	183	183	3.0 to 5.6
Whole Building	Miscellaneous measures	New other commercial; buildings	28	60	98	3.0 to 5.6
Whole Building	Miscellaneous measures	Existing non-buildings	209	209	209	not available
Whole Building	Miscellaneous measures	New non-buildings	18	42	68	not available
Space cooling	Cooling savings from interractive effects (lighting)	All existing large commercial	13	29	44	not applicable
Space heating	Heating penalty from interractive effects	All existing large commercial	-10	-19	-29	not applicable
Total			**2,159**	**2,754**	**3,072**	

Note: Savings from the Integrated Design Approach shown in this exhibit are from several end-uses; consequently, specific end-use values differ slightly from those in previous exhibits (e.g., a portion of the General Lighting savings shown in Exhibit 5.7 are shown under Integrated Design Approach in this exhibit.)

*Results are measured at the customer's point of use and do not include line losses.

5.6 INTERPRETATION OF RESULTS

Highlights of the results presented in the preceding exhibits are summarized below:

❑ **Savings by Service Region**

Exhibit 5.5 shows that the overall savings are distributed among the three service regions in "rough" approximation to the distribution of total annual electricity sales. By 2015/16, savings in the Lower Mainland (70% of total) moderately exceed its share of the total Reference Case consumption (66% of total). It is assumed that this is due, at least in part, to the higher concentration of large office and retail building segments, which provide above average savings opportunities.

❑ **Savings by Building Segment**

Exhibit 5.6 shows that the office (24%) and non-food retail (15%) segments account for the largest share of the total identified economic potential electricity savings among those segments that were subject to detailed modelling. These segments offer large potential savings due to the fact that almost all technologies are applicable. The magnitude of the savings is also related to the significant potential to reduce the lighting electricity use. The small commercial segment, which consists of the many small customers within each of the modelled building segments (e.g., office, hospital etc.), also represents approximately 27% of the total savings potential. Although savings per square foot of small commercial floor space are generally smaller than in the larger buildings, overall savings potential remains significant. This is due to the large number of customers (and floor space) that has been included in this segment based on the criteria defined at the outset of this study. As shown previously in Exhibit 2.3, the small commercial segment accounts for over 50% of the estimated floor space.

❑ **Savings by End-use and Technology**

Exhibits 5.7 and 5.8 show that efficient lighting technologies account for approximately 64% of the total economic potential savings. The technologies that achieve the reduction include:

- Conversion of remaining T12 fluorescent lighting to second-generation T8 lighting;
- Replacement of incandescent lighting with higher efficacy lighting (either CFLs or white LED lighting);
- HIF lighting to replace 400W metal-halide lighting in high-bay applications; and
- Integrated lighting controls in office buildings.

There are significant opportunities to reduce the high lighting electricity use (*see* Section 2.6). In a number of segments, there is an opportunity to replace the existing T12 fluorescent lighting with second-generation T8 lighting and to apply lighting re-designs that reduce the LPD by over 50%. In the case of existing large office buildings, it is possible to reduce the LPDs down from the market average of 1.8 W/sq.ft. to 0.7 W/sq.ft. (or even to 0.5 W/sq.ft.) by using integrated lighting controls systems such as Ergolight. Further savings are achieved by minimizing lighting use during unoccupied hours.

Exhibit 5.9 compares the baseline lighting power densities (LPDs) with the calculated LPDs that would result from implementing the technologies listed above.

Exhibit 5.9: Baseline LPDs versus Economic Potential LPDs for General Lighting in Selected Existing Buildings

Building Segment	Baseline LPD W/sq.ft.	Economic Potential LPD W/sq.ft.	Reduction (%)
Large Office	1.8	0.7	61
Medium Office	1.8	0.7	61
Large Non-food Retail	3.1	1.9	39
Medium Non-food Retail	2.3	1.8	22
Large Hotel	1.2	0.7	42
Medium Hotel	1.2	0.6	50
Hospital	0.7	0.5	29
Large School	1.1	0.9	19
Medium School	1.0	0.8	20

The use of more-efficient HVAC systems accounts for approximately 11% of identified electricity savings. The most significant contribution to these savings arise from:

- Reduced operating hours during the unoccupied period through recommissioning and installation of a second-generation BAS/FMS;
- Optimization of fan efficiency through recommissioning;
- Application of variable speed pumping;
- Interactive effects in variable air volume (VAV) systems from reduced internal heat loads from lighting retrofits; and
- Use of the integrated design approach in new construction.

5.6.1 Caveats on Interpretation of Results

A systems approach, consistent with that employed in the original CPR, was used to model the energy impacts of the efficiency upgrades presented in the preceding section. In the absence of a systems approach an accurate assessment of the total contribution of the electrical efficiency upgrades would not be possible. This is because interactive effects occur among end uses as a result of the upgrade options. In cases where more than one technology affects a given end use, the net impact of the upgrade options is often different than the sum of their individual impacts. For example, lighting efficiency upgrades reduce "waste heat" and thereby increase space heating loads while also reducing space cooling requirements. An accurate assessment of the overall impact of the lighting upgrade requires that the "net effect" of these interactions be assessed. Thus, all the savings presented in this section are based on actual building simulation model runs.

The above consideration means that the electricity savings shown in this section are for the identified "bundle" of upgrade options that affect each end use. Calculation of the potential contribution of an individual technology would require a separate model run.

6. ACHIEVABLE POTENTIAL ELECTRICITY SAVINGS

6.1 INTRODUCTION

This section presents the Commercial Sector Achievable Potential Electricity Savings for the study period (FYs 2000/01 to 2015/16). The Achievable Potential is defined as the proportion of the savings identified in the Economic Potential Forecast that could realistically be achieved within the study period.

The remainder of this discussion is organized into the following subsections:

- Description of Achievable Potential
- Approach to the Estimation of Achievable Potential
- Presentation of Results.

6.2 DESCRIPTION OF ACHIEVABLE POTENTIAL

Achievable Potential recognizes that in many instances it is difficult to induce all customers to purchase and install all the electrical efficiency technologies that meet the criteria defined by the Economic Potential Forecast. For example, customer decisions to implement electrical efficiency measures can be constrained by important factors such as:

- Higher first cost of efficient product(s)
- Need to recover investment costs in a short period (payback)
- Lack of product performance information
- Lack of product availability.

The rate at which customers accept and purchase energy-efficient products will be influenced by the level of financial incentives, information and other measures put in place by BC Hydro, governments and the private sector to remove barriers such as those noted above.[80]

Exhibit 6.1 presents the level of electricity consumption that is estimated in the Achievable Potential scenarios. As illustrated, the Achievable Potential scenarios are "banded" by the two forecasts presented in previous sections, namely: the Economic Potential Forecast (everything with a CCE < 06 ¢/kWh is implemented) and the Reference Case (natural conservation only). As illustrated in Exhibit 6.1, electricity savings under Achievable Potential are typically less than in the Economic Potential Forecast. Two key considerations contribute to this outcome:

- **Savings per Participant**. The bundle of measures in the Economic Potential Forecast was selected based on BC Hydro's economic criteria, not that of the customer (which has not yet been considered). For example, the economic criteria used by BC Hydro employ a discount rate of 8%, which is lower than the levels typically used by the private sector, and use the avoided cost of new electricity supply as an investment decision threshold. In contrast, customers typically make their electrical efficiency investment decisions based on the investment's simple payback period, which is determined by the investment cost and the current price that they pay for electricity. Thus, the measures included in the Economic Potential Forecast may be more aggressive than those that the customer would be willing to invest in (even with BC Hydro intervention). As a result, participant electricity savings in the Economic Potential Forecast may exceed levels contained in the Achievable Potential scenarios.

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[80] Further discussion of market barriers facing energy-efficient technologies, together with possible interventions is provided in Appendix H.

- **Rate of Market Penetration**. In the Economic Potential Forecast, efficient new technologies are assumed to fully penetrate the market as soon as it is financially attractive to do so. However, the Achievable Potential recognizes that under "real world" conditions, the rate at which customers are likely to implement new technologies will be influenced by additional practical considerations and will, therefore, occur more slowly than under the assumptions employed in the Economic Potential Forecast.

Exhibit 6.1 also shows that future electricity consumption under the Reference Case is greater than in either of the two Achievable Potential forecasts. This is because the Reference Case represents a "worst case" situation in which there are no additional BC Hydro market interventions and hence no additional electricity savings beyond those that occur "naturally".

Any estimate of Achievable Potential over a 15-year period is necessarily subject to uncertainty; therefore, Exhibit 6.1 presents the achievable results as a band of possibilities, rather than a single line. For example, at the time of this study, there are a number of known external factors that could significantly influence the achievable estimates presented in this section (e.g., implications of Canada's ratification of the Kyoto Protocol, changes to U.S. federal government energy policy and regional initiatives such as the Sustainable Region Initiative). Given the preceding considerations, two Achievable Potential scenarios are presented: "most likely" and "upper".[81]

- The ***"Most Likely" Achievable Potential*** assumes B.C. market conditions that are similar to those contained in the Reference Case. That is, the customers' awareness of energy efficiency and their motivation levels remain similar to those in the recent past, technology improvements continue at historical levels and new energy performance standards continue as per current known schedules. It also assumes that BC Hydro's ability to influence customers' decisions towards increased investments in energy efficiency remains "roughly" in line with previous Power Smart experience.

- The **"Upper"** ***Achievable Potential*** assumes that B.C. market conditions become more supportive of investing in energy efficiency. For example, this scenario assumes that the ratification of the Kyoto Protocol leads to new federal government initiatives that increase customers' awareness of energy efficiency and their motivation. These conditions also provide additional opportunities to leverage Power Smart program resources through partnering with other organizations (e.g., the federal government). It also assumes that current U.S. federal energy policy becomes more supportive of energy efficiency. This is particularly critical to assumptions about the timing and the performance levels of upgraded appliance and equipment energy performance standards or regulations.[82]

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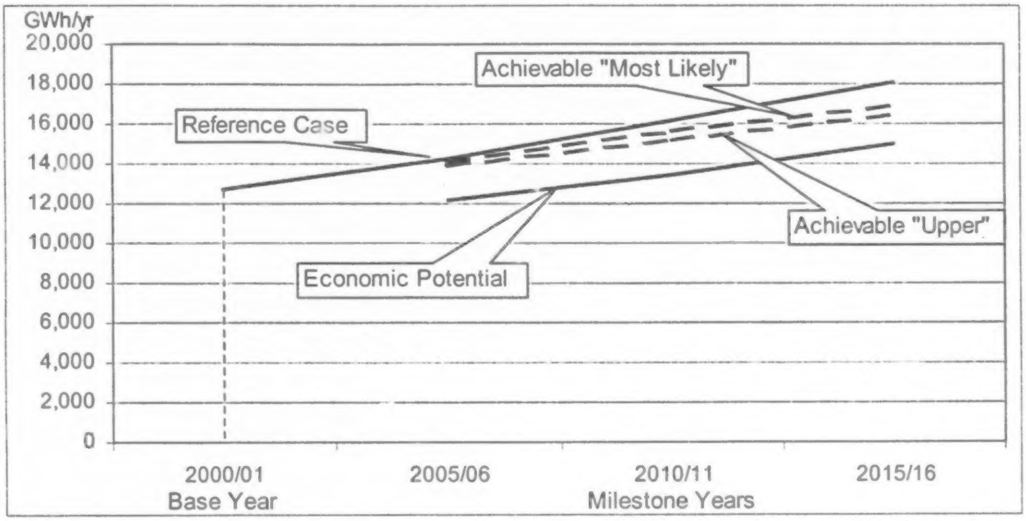
[81] This is the upper limit of the impact of BC Hydro initiatives. It is not the upper limit of electricity conservation.

Exhibit 6.1: Annual Electricity Consumption—Achievable Potential Relative to Reference Case and Economic Potential Forecasts for the Commercial Sector, (GWh/yr.)



6.2.1 Achievable Potential Versus Detailed Program Design

It should also be emphasized that estimating Achievable Potential is not synonymous either with the setting of specific Power Smart targets or with program design. Although both are closely linked to the discussion of Achievable Potential, they involve more detailed analysis that is beyond the scope of this study.

Exhibit 6.2 illustrates the relationship between Achievable Potential and the more detailed program design.

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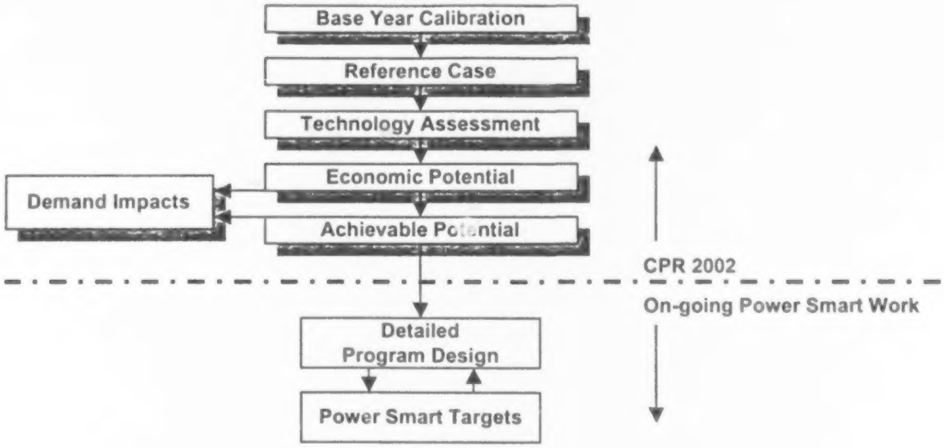
[82] The estimate of customer participation rates for future Power Smart initiatives in the "Upper" scenario assumed that there would be some increase in electricity rates charged by BC Hydro. However, there was no examination of different rate designs or the possible differential impacts of different levels of rate increases or alternative rate designs.

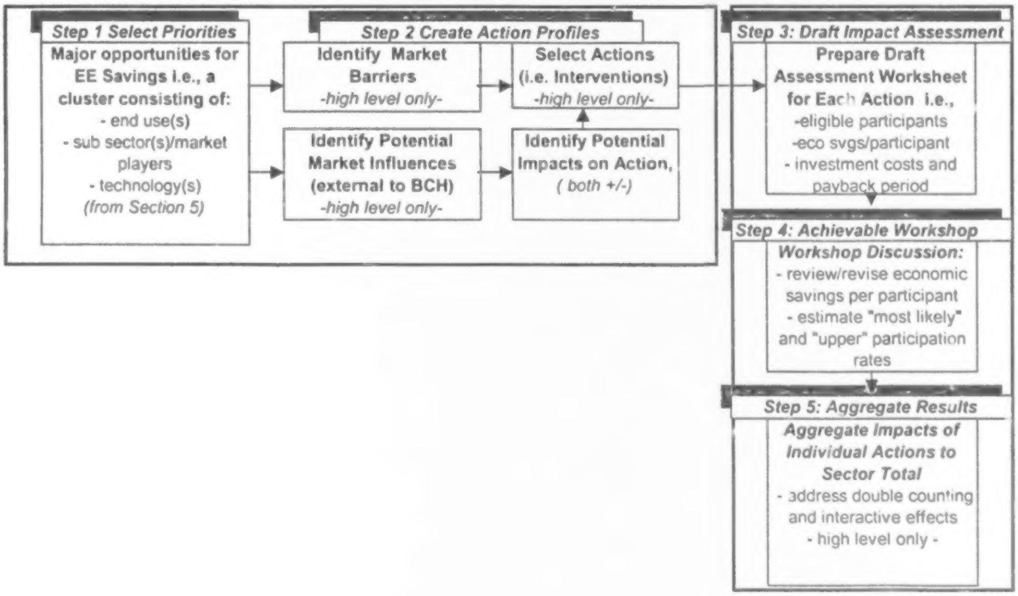
Exhibit 6.2: Achievable Potential versus Detailed Program Design


Base Year Calibration
Reference Case
Technology Assessment
Economic Potential
Demand Impacts
Achievable Potential
CPR 2002
On-going Power Smart Work
Detailed Program Design
Power Smart Targets

6.3 APPROACH TO THE ESTIMATION OF ACHIEVABLE POTENTIAL

Achievable Potential was estimated in a five-step approach. A schematic showing the major steps is shown in Exhibit 6.3 and each step is discussed below.

Exhibit 6.3: Flow Chart for Estimating Achievable Potential


Step 1 Select Priorities
Major opportunities for EE Savings i.e., a cluster consisting of:
- end use(s)
- sub sector(s)/market players
- technology(s)
(from Section 5)
Step 2 Create Action Profiles
Identify Market Barriers
-high level only-
Select Actions (i.e. Interventions)
-high level only-
Identify Potential Market Influences (external to BCH)
-high level only-
Identify Potential Impacts on Action,
(both +/-)
Step 3: Draft Impact Assessment
Prepare Draft Assessment Worksheet for Each Action i.e.,
-eligible participants
-eco svgs/participant
- investment costs and payback period
Step 4: Achievable Workshop
Workshop Discussion:
- review/revise economic savings per participant
- estimate "most likely" and "upper" participation rates
Step 5: Aggregate Results
Aggregate Impacts of Individual Actions to Sector Total
- address double counting and interactive effects
- high level only -

6.3.1 Step 1: Select Priorities

The first step in developing the Achievable Potential estimates required that the energy saving opportunities identified in the Economic Potential Forecast be "bundled" into a set of Actions that would facilitate the subsequent assessment of their potential market penetration.

A summary of the selected Actions is provided in Exhibit 6.4. As illustrated, the Actions have been bundled by end use and, for each Action, Exhibit 6.4 shows the Action name, the target end use(s), the target subsectors and technologies, and the approximate percentage that it represents of the total commercial sector electricity savings contained in the Economic Potential Forecast.

Exhibit 6.4: Commercial Sector Actions

Action		Target End-use(s)	Vintage(s)	Technologies & Target Segments	% Economic Savings (approx)
#	Name				
C1	**Lighting Retrofit**	General lighting	Existing	Lighting redesign, advanced T8 & Ergolight controls; large and medium offices Lighting redesign & advanced T8; all remaining commercial	24.0
		Architectural lighting	Existing	Advanced T8, CFLs and white LED; all commercial	4.5
		High-bay lighting	Existing	High-intensity fluorescents; all commercial, schools are special target due to gym opportunities	1.0
C2	**HVAC Retrofit**	HVAC	Existing	Recommissioning, 2nd generation BAS, VSDs; all large commercial	5.5
C3	**Heating & Cooling Retrofit**	Space heating and cooling	Existing	Advanced cold-climate heat pump; large & medium hotels and nursing homes High-efficiency chillers; large & medium offices, retail and hospitals	1.0
C4	**Integrated Design**	Whole building	New	Integrated design approach; all new large	15.0
C5	**Small Commercial Retrofit & Design**	Small commercial lighting and HVAC, DHW	New	Lighting redesign, advanced T8, CFLs and white LED, HIFs 2nd generation BAS Low-flow devices	27.5
C6	**Energy Star Computers & Electronic Equipment**	Plug Loads, computer equipment, DHW	Both	Energy Star compliant computers and equipment; all commercial Low flow devices; all commercial not included in C5	2.5
C7	**Commercial Refrigeration Retrofit & Design**	Refrigeration	Both	Multiplexed compressors, display cases, head pressure controls, smart controls; food retail	1.5
C8	**Miscellaneous**	Misc (e.g., elevators, exterior lighting etc)		Other buildings and non-buildings	18.0

6.3.2 Step 2: Create Action Profiles

The next step involved developing brief profiles for each of the Actions noted above in Exhibit 6.4. A sample profile for ***Action C1—Commercial Lighting Efficiency*** is presented in Exhibit 6.5. (For profiles of each of the remaining Actions *see* Appendix H.)

The purpose of the Action Profiles was to provide a "high-level" logic framework that would serve as a guide for participant discussions in the Achievable Workshop (*see below*). The intent was to define a broad rationale and direction without getting into the much greater detail required of program design, which as noted previously is beyond the scope of this project.

As illustrated in Exhibit 6.5, each Action Profile addresses the following areas:

- *Goal*—provides a summary statement of the broad goal and rationale for the Action.
- ***Target Technologies and Subsegment***—highlights the major technologies and the subsegments where the most significant electricity savings opportunities have been identified in the Economic Potential Forecast.
- ***Target Stakeholder Groups***—identifies key market players that would be expected to be involved in the actual delivery of services. The list of stakeholders shown is intended to be "indicative" and is by no means comprehensive.
- ***Key Barriers and Interventions***—identifies key market barriers that are currently constraining the increased penetration of the electrical efficiency technologies or measures. Interventions for addressing the identified barriers are noted. Again, it is recognized that the interventions are not necessarily comprehensive; rather, their primary purpose was to help guide the workshop discussions. A listing of generalized electrical efficiency market barriers and interventions is provided in Appendix H.
- ***Time Frame***—identifies the potential timing of activities with the intent of assisting workshop participants to envision possible customer participation rates.
- ***Relationship to Other Actions***—identifies possible synergies with other Actions that may affect participant views on possible customer participation rates.

Exhibit 6.5: Sample Commercial Action Profile

Action Profile C 1—Lighting Retrofit

Goal:

The goal of this Action is the efficient retrofit of general, architectural and high-bay lighting systems in existing commercial buildings. The Action will promote reduced connected lighting power densities (LPDs) and operating hours through the use of high efficacy lighting systems and controls, where applicable. Baseline data indicate that there is still a significant portion of T12 lighting system with high LPDs in the commercial sector. In addition, energy use data and limited metering data (large offices) suggest long hours of operation.

The primary focus of this Action is on the large and medium commercial buildings, as small commercial buildings are addressed separately under Action #5.

Target Technologies and Subsegments:

General lighting	Lighting redesign, advanced T8 & Ergolight controls; large and medium offices Lighting redesign & advanced T8; all remaining commercial
Architectural lighting	Advanced T8, CFLs and white LED; all large & medium commercial
High-bay lighting	High-intensity fluorescents; all commercial; schools and university/colleges are special targets due to gym opportunities. Other opportunities include low bay warehouses and/or applications where the baseline is 400-W Metal-halide lighting or less

Target Stakeholder Group:

- Owners, developers, facility managers, BOMA members
- Lighting manufacturers and suppliers
- Contractors
- BC Ministry of Energy re: lighting standards
- Lighting designers e.g., IES local chapters

Key Barriers and Interventions:

Experience to date indicates that the most significant barriers affecting this opportunity are:

- Lack of customer EE awareness (e.g., energy savings, improved light quality, longer life of advanced T8 systems)
- Split incentive (especially in lease arrangements)
- Transaction costs
- Financing (especially applicable to the "cash-short" institutional sector such as schools and universities)

This Action will address the above barriers by combining the following interventions:

- Information and promotion
- Specialized customer support (e.g., provide training on lease agreement language to BOMA members and/or education on how energy efficiency can increase property value)
- Vendor & customers links (e.g., contractor/customer links; contractor certification)
- EE procurement (e.g., help create buying groups for institutional customers that will encourage use of EE products)
- Financing (customer and vendor rebates)
- Standards and regulation (accelerated increase in provincial minimum efficiency performance standards for fluorescent lamp and ballast products)

Time Frame:

Start in 2003; financial incentives to 2008; new performance efficiency standards post 2008.

Relationship to Other Actions:

This Action complements activities envisioned under Actions C2 (HVAC) and C3 for large commercial (HE chiller replacement).

6.3.3 Step 3: Prepare Draft Action Assessment Worksheets

A draft Assessment Worksheet was prepared for each Action Profile in advance of the Achievable Workshop (*see* Step 4). The Assessment Worksheets complemented the information contained in the Action Profiles by providing quantitative data on the potential energy savings for each Action as well as providing information on the size and composition of the eligible population of potential participants. Energy savings and population data were taken from the detailed modelling results contained in the Economic Potential Forecast.

A sample Assessment Worksheet[83] for ***Action C1—Commercial Lighting Efficiency*** is presented in Exhibit 6.6. (For worksheets[84] on the remaining Actions, *see* Appendix H.) As illustrated in Exhibit 6.6, each Action Assessment Worksheet addresses the following areas:

- ***Approximate % of Action Savings***—shows the contribution of individual subsectors to the total energy savings represented by each Action. For example, the previous Exhibit 6.4 showed that lighting accounts for about 30% of the commercial electricity savings contained in the Economic Potential Forecast. The first entry in Exhibit 6.6 shows that large offices account for about 33% of those lighting savings.
- ***Economic Savings to FY 2015/16***—shows the total economic savings to the milestone year 2015/16 for the measures included in the Action. As applicable, the savings are further broken out by technology and/or end use.
- ***Total Applicable Floorspace***—shows the total amount of floorspace that could theoretically take part in the Action. Numbers shown are from the eligible populations used in the Economic Potential Forecast. The actual number of buildings is also shown where more detailed data are available.
- ***Major Technologies and Contribution to Economic Savings***—provides additional detail on the composition of the economic savings for the Action. It was particularly intended to assist workshop participants in their discussions of potential participation rates.

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[83] The notes shown at the bottom of Exhibit 6.6 apply to the complete set of worksheets. As Exhibit 6.6 shows only a partial worksheet, all the notes do not apply.

[84] In the workshop it was determined that some Actions needed further definition to provide the proper detail.

Exhibit 6.6: Sample Worksheet (partial) Action C1—Lighting Efficiency

Subsector		**Large Office**			**Medium Office**			**Large Non-food Retail**			**Medium Non-food Retail**			**University/College**		
Approx % of Action Svgs		33.30%			8.70%			23.20%			5.10%			10.70%		
Total Economic Savings (GWh) to 2015/16	General	264			73			167 note 1			42 note 1			96		
	Arch (incl.	34			4			40			3			0		
	H Bay	0			0			0			0			0		
Total Applicable Floorspace (ft2)		50,400,000 247 bldgs/facilities			13,900,000 242 bldgs/facilities			36,000,000 161 bldgs/facilities			11,700,000 145 bldgs/facilities			26,400,000 31 bldgs/facilities		
Major Technologies & Contribution to Economic Savings (% of eco)	Dsgn +	36%			41%									30%		
	Controls	32%			32%											
	AT8	24%			24%			82%			90%			69%		
	CFL's/LED	8%			3%			8%			5%			1%		
	HIF							10%			5%					
Base/Target kWh//sq.ft./yr	Base	9.9			9.4			16.4			15.2			8.7		
W/sq.ft	LPD	1.8			1.8			3			2.5			1.75		
W/sq.ft	Target	0.7			0.7			1.9			1.8			0.9		
Approx. Breakdown of Economic Savings (KWh/sq.ft./yr)	General	5.7			5.7			4.5			4			4		
	Arch	0.5			0.2			0.5			0.2			0		
	H Bay	0			0			0.2			0			0		
Savings Adjustment Factor (if applicable)																
Approx CCE (¢/kWh)		4 - 5.5			4			3			3			4		
Approx. payback (years)		8.8			8.8			6.6			6.6			8.8		
Participation Rates, by Year (% of GWh		*"05/06"*	*"10/11"*	*"15/16"*	*"05/06"*	*"10/11"*	*"15/16"*	*"05/06"*	*"10/11"*	*"15/16"*	*"05/06"*	*"10/11"*	*"15/16"*	*"05/06"*	*"10/11"*	*"15/16"*
Lighting Redesign	*Most Likely*	5%	15%	25%	5%	15%	25%	10%	30%	70%	10%	30%	70%	20%	35%	50%
	Upper	15%	30%	50%	15%	30%	50%	20%	50%	80%	20%	50%	80%	25%	40%	60%
Direct Conversion to T8	*Most Likely*	10%	50%	100%	10%	50%	100%		note 4			note 4		25%	75%	90%
	Upper	20%	75%	100%	20%	75%	100%							30%	80%	100%
Controls	*Most Likely*	5%	15%	25%	5%	15%	25%								note 6	
	Upper	15%	30%	50%	15%	30%	50%									
CFL's/LED	*Most Likely*	10%	50%	90%	10%	50%	90%							15%	40%	90%
	Upper	15%	70%	95%	15%	70%	95%							25%	50%	95%
Action Savings, by Year (GWh)		*"05/06"*	*"10/11"*	*"15/16"*	*"05/06"*	*"10/11"*	*"15/16"*	*"05/06"*	*"10/11"*	*"15/16"*	*"05/06"*	*"10/11"*	*"15/16"*	*"05/06"*	*"10/11"*	*"15/16"*
Lighting Redesign	*Most Likely*	5.4	16.1	26.8	1.6	4.7	7.9	20.7	62.1	144.9	4.5	13.5	31.5	5.8	10.1	14.4
	Upper	16.1	32.2	53.6	4.7	9.5	15.8	41.4	103.5	165.6	9.0	22.5	36.0	7.2	11.5	17.3
Direct Conversion to T8	*Most Likely*	7.2	35.8	71.5	1.8	9.2	18.5							16.6	49.7	59.6
	Upper	14.3	53.6	71.5	3.7	13.9	18.5							19.9	53.0	66.2
Controls	*Most Likely*	4.8	14.3	23.8	1.2	3.7	6.2									
	Upper	14.3	28.6	47.7	3.7	7.4	12.3									
CFL's/LED	*Most Likely*	2.4	11.9	21.5	0.2	1.2	2.1							0.1	0.4	0.9
	Upper	3.6	16.7	22.6	0.3	1.6	2.2							0.2	0.5	0.9
Total	*Most Likely*	19.7	78.1	143.6	4.9	18.8	34.6	20.7	62.1	144.9	4.5	13.5	31.5	22.5	60.1	74.9
	Upper	48.3	131.1	195.5	12.5	32.3	48.8	41.4	103.5	165.6	9.0	22.5	36.0	27.3	65.0	84.4

Notes:

1 includes accent lights
2 office area
3 includes some T8
4 values are for total packag
5 values are for total package--bit more motivated than large non-food retail
6 first set is redesign + AT8; second set is incr T12 to T8; are additive
7 suites
8 first set is T12 to T8 conversion; second set is HIF

- ***Base/Target***—shows energy use intensities assumed in the Reference Case (Base) as well as target levels contained in the Economic Potential Forecast. This information was particularly intended to assist workshop participants to understand the level of technical improvements that are contained in the Economic Potential Forecast.

- ***Approximate Breakdown of Savings***—shows the approximate level of savings that are assigned to each of the end uses or technologies (as applicable) that are contained in the Economic Potential Forecast. Savings are expressed as annual kilowatt hours per square foot. In the example shown in Exhibit 6.6, the annual savings from this Action for the "general lighting" end use are estimated to be 5.7 kWh/sq.ft.

- ***Savings Adjustment Factor***—provides a record of any decisions to de-rate the "optimized" savings contained in the Economic Potential Forecast to levels that better account for practical customer considerations. This entry was completed during the workshop, or in subsequent discussions with workshop participants.[85]

- ***Approximate CCE***—shows the approximate cost of conserved energy (CCE) for the measure(s) included within each Action. Where multiple measures are included, a weighted average value is presented. The CCE provides an indication of the relative economic attractiveness of the electrical efficiency measures from BC Hydro's perspective. For the purposes of the workshop, this information provided participants with an indication of the scope for using financial incentives to influence customer participation rates.

- ***Customer Payback***—shows the simple payback from the customer's perspective for the package of electrical efficiency measures included in the Action. The customer's payback is calculated based on the full cost of the measure (i.e., no program incentive) and assuming current BC Hydro commercial customer rates. This information provides an indication of the level of attractiveness that the Action measures would present to customers. This provided an important reference point for the workshop participants when considering potential participation rates. When combined with the preceding CCE information, participants were able to "roughly" estimate the level of financial incentives that could be employed to increase the Action's attractiveness to customers without making the measures economically unattractive to BC Hydro.

For example, measures having a long payback period from the customer's perspective but having an attractive CCE from BC Hydro's perspective[86] provide opportunity for BC Hydro to reduce the customer's payback by providing financial incentives. Measures having both long paybacks and relatively high CCEs do not provide the same opportunity for using financial incentives to increase their attractiveness to customers and, hence, to increase customer participation rates.

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[85] It was not possible to discuss all the Action Profiles during the one-day workshop. Consequently, follow up discussions were held with core BC Hydro personnel after the workshop.

[86] This situation can occur with measures that have a relatively long service life.

- ***Participation Rates***—show the percentage of economic savings that workshop participants concluded could be achieved in each milestone period. For example, Exhibit 6.6 shows a participation rate of 15% (most likely) for lighting redesign in large offices by the year FY 2010/11. This means that by the year FY 2010/11, 15% of the eligible large office floor space will have installed the lighting redesign measures that were included in the Economic Potential Forecast. As noted in the introduction to this section, two achievable levels are shown: "most likely" and "upper". As it was not possible to cover all the Action Profiles during the workshop, some of the values shown were developed in collaboration with BC Hydro program personnel following the workshop.

- ***Action Savings by Year***—shows the calculated electricity savings in each milestone year based on the savings and participation rates presented in the preceding rows of the Worksheet. Continuing with the above lighting redesign example, Exhibit 6.6 shows that if the above 15% participation rate is achieved by FY 2010/11, then the electricity savings in FY 2010/11 due to lighting redesign in large offices will be 16.1 GWh/yr. ("most likely"). If the upper participation rate of 30% is achieved, then the electricity savings in 2010/11 due to lighting redesign in large offices will be 32.2 GWh/yr. ("upper").

6.3.4 Step 4: Achievable Workshop

The most critical step in developing the estimates of Achievable Potential for the commercial sector was a one-day Achievable Workshop that was held on 20 November 2002. Workshop participants consisted of core members of the client and consultant team as well as key program and technical personnel from BC Hydro's commercial Power Smart programs. Participating BC Hydro personnel brought to the workshop many years of experience in the design and delivery of electrical efficiency programs within the B.C. market.

The purpose of this workshop was twofold:

- To promote discussion between the consultants and the Power Smart personnel regarding the identified electrical efficiency opportunities.
- To promote discussions among the BC Hydro personnel themselves related to how much of the identified economic savings could realistically be achieved over the study period.

The discussion of each Action Profile began with a brief presentation by the consultants. The floor was then opened to participant discussion of the key factors affecting each of the market segments and technical opportunities contained in the Action Profile and accompanying Worksheet.

Following discussion of the broad market and intervention conditions affecting the Action, workshop participant views were recorded on "most likely" and "upper" customer participation rates. General agreement was sought on rates to be carried forward into the analysis; estimates were rounded down for "most likely" and rounded up for "upper" estimates.

As noted earlier, it was not possible to fully address all Actions in the one-day workshop. Consequently, the workshop focused on the "big-ticket" Actions and follow up discussions were held with BC Hydro program personnel after the workshop. The values shown in the appendices[87] and in the following summary tables incorporate the results of the two sets of inputs.

6.3.5 Step 5: Aggregate Action Results

The final step involved aggregating the results of the individual Actions to provide an estimate of the potential achievable savings for the total commercial sector. Before simply adding up the individual Action results, it was necessary to assess whether "double counting" of savings and "interactive effects" continued to be properly addressed. The savings presented in the Economic Potential Forecast were generated using building energy use simulation software that automatically calculates the net energy impact of multiple measures and accounts for interactive effects between individual measures (e.g., the reduced cooling loads created by more efficient lighting systems). However, the Action Profiles considered some of the measures in isolation, which, in theory, means that their net saving impacts and interactive effects may differ from those in the Economic Potential Forecast. As it is not possible to predict exactly which bundle of measures each customer will choose, it is not possible to completely account for the final net impact of these effects.

The achievable savings presented below were calculated as a percentage of those contained in the Economic Potential Forecast; this means interactive and double counting effects have largely been accounted for. However, as the final mix of measures included in the Achievable Potential may differ from those in the Economic Potential Forecast, the resulting impacts may differ slightly.

6.4 RESULTS

Exhibit 6.7 presents a summary of the Achievable Potential savings under the "most likely" and "upper" scenarios. The savings values shown are relative to the Reference Case and represent the total cumulative electricity savings at the end of each milestone year.[88] For example, Exhibit 6.7 shows that Action C1—Lighting will achieve an annual saving of about 96 GWh/yr. by FY 2005/06 under the "most likely" scenario. This annual savings increases to 283 GWh/yr. by 2010/11, again under the "most likely" scenario.

As illustrated in the following exhibits, savings under the Achievable Potential scenarios are significantly less than the Economic Potential savings presented previously in Section 5. Overall, Achievable savings by FY 2015/16 represent approximately 37% ("most likely") and 53% ("upper") of the Economic Potential savings. The primary reason for the gap between the Achievable and the Economic savings is the different criteria that are used in the two cases. The Economic Potential savings are based on criteria that reflect BC Hydro's investment

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[87] Appendices are contained in a separate volume.

[88] Savings shown for FY 2005/06 include the impacts of new Power Smart activities implemented since the base year of FY 2000/01.

requirements and that are not constrained by market barriers. These criteria are very different than those that commercial building owners/operators use to make investment decisions. For example, the package of lighting efficiency measures shown in Exhibit 6.6 for the large office segment meet the criteria defined in the Economic Potential scenario (i.e., a CCE less than $0.06/kWh); therefore, the Economic Potential scenario assumes that the lighting measures fully penetrate the large office market over the study period. However, Achievable Potential savings recognize that even with utility incentives, it is likely that customer payback periods for the same package of lighting measures will not be financially attractive to all customers relative to other available investment opportunities. Similarly, the Achievable Potential estimates recognize that market barriers such as split incentives between landlord and tenants provide further challenges to the achievement of customer participation. Given that this study's results are intended to provide a solid basis for BC Hydro's DSM investments, assumptions about customer willingness to invest have necessarily taken these real life factors into consideration and, in some cases, the results may be conservative.

Exhibits 6.8 ("most likely") and 6.9 ("upper") show the estimated electricity savings in the milestone year 2015/16 for each Action in the form of supply curves that also incorporate the Cost of Conserved Energy (CCE). This view, therefore, shows the level of electricity savings that could be achieved under various investment thresholds.

Exhibits 6.10 ("most likely") and 6.11 ("upper") show the same Achievable Potential results, sorted by building segment, end use and milestone year.

Exhibit 6.7: Summary of Achievable Savings, by Action for "Most Likely" & "Upper" Scenarios*

Service Region	Annual Electricity Savings (GWh/yr.), by Milestone Year					
	2005/06		2010/11		2015/16	
Action	Most Likely	Upper	Most Likely	Upper	Most Likely	Upper
C1 - Lighting	95.8	174.3	283.3	426.4	510.5	634.2
C2 - HVAC Retrofit	4.5	10.3	20.6	53.4	54.0	92.4
C3 - Heating and Cooling Retrofit	1.0	2.1	4.2	10.5	8.5	19.0
C4 - High Perf. Large Com. Buildings	14.6	31.1	58.9	110.5	129.9	245.1
C5 - Small Commercial Retrofit and Design	41.4	111.5	134.3	249.0	264.1	372.9
C6 - Energy Star Computers and Electronic Equipment	3.8	7.5	22.5	45.0	37.5	67.5
C7 - Commercial Refrigeration Retrofit	1.6	3.2	5.7	8.9	11.6	20.8
C8 - Other Commercial Buildings	15.0	30.0	30.0	60.0	60.0	90.0
C9 - Non-buildings	12.9	25.8	25.8	51.6	51.6	77.4
Total BC Hydro	**190.5**	**395.8**	**585.4**	**1015.2**	**1127.7**	**1619.3**
Lower Mainland						
C1 - Lighting	65.7	119.6	200.9	302.3	364.0	452.2
C2 - HVAC Retrofit	3.1	7.1	14.6	37.9	38.5	65.9
C3 - Heating and Cooling Retrofit	0.7	1.4	3.0	7.4	6.0	13.5
C4 - High Perf. Large Com. Buildings	10.0	21.3	41.8	78.3	92.6	174.8
C5 - Small Commercial Retrofit and Design	28.4	76.5	95.2	176.5	188.3	265.9
C6 - Energy Star Computers and Electronic Equipment	2.6	5.1	16.0	31.9	26.7	48.1
C7 - Commercial Refrigeration Retrofit	1.1	2.2	4.0	6.3	8.3	14.8
C8 - Other Commercial Buildings	10.3	20.6	21.3	42.5	42.8	64.2
C9 - Non-buildings	8.8	17.7	18.3	36.6	36.8	55.2
Total Lower Mainland	**130.7**	**271.5**	**415.0**	**719.8**	**804.1**	**1154.6**
Vancouver Island						
C1 - Lighting	14.5	26.3	40.8	61.4	73.0	90.7
C2 - HVAC Retrofit	0.7	1.6	3.0	7.7	7.7	13.2
C3 - Heating and Cooling Retrofit	0.2	0.3	0.6	1.5	1.2	2.7
C4 - High Perf. Large Com. Buildings	2.2	4.7	8.5	15.9	18.6	35.1
C5 - Small Commercial Retrofit and Design	6.3	16.8	19.3	35.9	37.8	53.3
C6 - Energy Star Computers and Electronic Equipment	0.6	1.1	3.2	6.5	5.4	9.7
C7 - Commercial Refrigeration Retrofit	0.2	0.5	0.8	1.3	1.7	3.0
C8 - Other Commercial Buildings	2.3	4.5	4.3	8.6	8.6	12.9
C9 - Non-buildings	1.9	3.9	3.7	7.4	7.4	11.1
Total Vancouver Island	**28.8**	**59.8**	**84.3**	**146.2**	**161.3**	**231.6**
Interior						
C1 - Lighting	15.6	28.4	41.6	62.7	73.5	91.3
C2 - HVAC Retrofit	0.7	1.7	3.0	7.9	7.8	13.3
C3 - Heating and Cooling Retrofit	0.2	0.3	0.6	1.5	1.2	2.7
C4 - High Perf. Large Com. Buildings	2.4	5.1	8.7	16.2	18.7	35.3
C5 - Small Commercial Retrofit and Design	6.7	18.2	19.7	36.6	38.0	53.7
C6 - Energy Star Computers and Electronic Equipment	0.6	1.2	3.3	6.6	5.4	9.7
C7 - Commercial Refrigeration Retrofit	0.3	0.5	0.8	1.3	1.7	3.0
C8 - Other Commercial Buildings	2.4	4.9	4.4	8.8	8.6	13.0
C9 - Non-buildings	2.1	4.2	3.8	7.6	7.4	11.1
Total Interior	**31.0**	**64.5**	**86.1**	**149.2**	**162.4**	**233.2**

*Results are measured at the customer's point of use and do not include line losses

Exhibit 6.8: Supply Curve of Commercial Sector Actions—Cumulative Savings of Electricity in Milestone Year 2015/16 for "Most Likely" Scenario, (GWh/yr.)

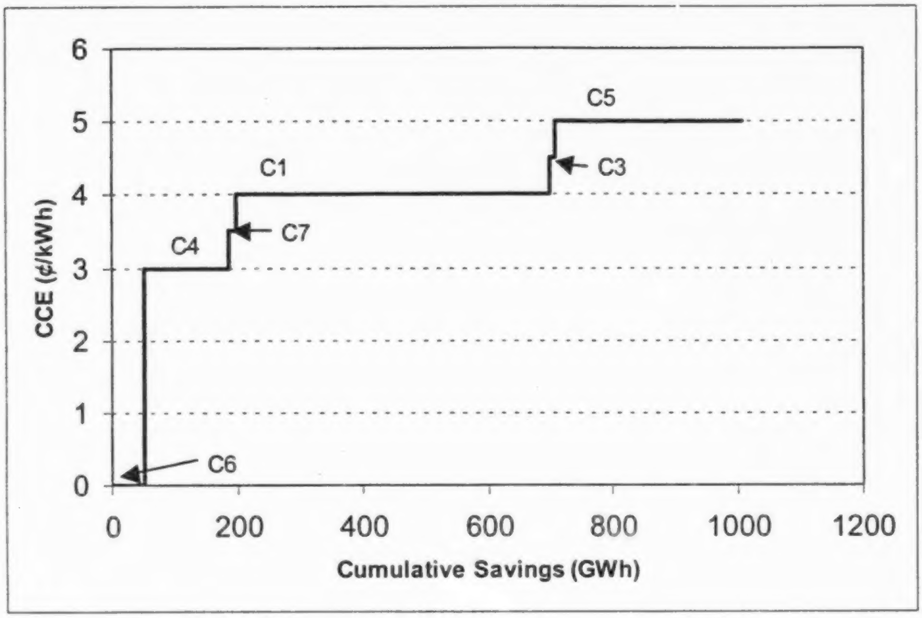

Exhibit 6.9: Supply Curve of Commercial Sector Actions—Cumulative Savings of Electricity in Milestone Year 2015/16 for "Upper" Scenario, (GWh/yr.)

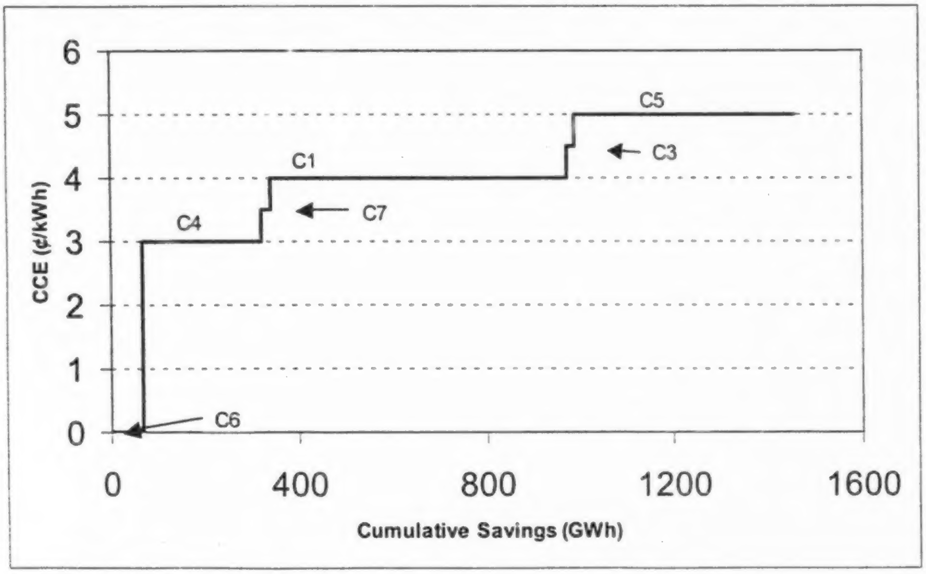

Exhibit 6.10a: Achievable Savings by End Use for "Most Likely" Scenario in FY 2005/06, (GWh/yr.)*

Segment	End-use													
	Lighting		HVAC		Sp Heat, Cool and DHW		Refrigeration		Plug Load		Integrated Design - New		Total	
	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%
Large Office	19.67	16%	1.82	32%	0.48	47%			3.25	87%	1.86	7%	27.1	14%
Medium Office	4.89	4%	0.36	6%	0.09	8%			0.35	9%	0.58	2%	6.3	3%
Large Non-food Retail	20.70	17%	0.50	9%	0.34	33%					7.35	28%	28.9	15%
Medium Non-food Retail	4.50	4%	0.04	1%	0.05	4%					1.60	6%	6.2	3%
Food Retail	1.11	1%					1.60	100%			<0.001	<0.01%	2.7	1%
Large Hotel	2.60	2%	0.005	0.1%	0.01	1%					0.28	1%	2.9	2%
Medium Hotel/Motel	1.30	1%			0.02	2%					0.18	1%	1.5	1%
Hospital	4.00	3%	0.29	5%	0.05	5%			0.10	3%	0.35	1%	4.8	3%
Nursing Homes	0.50	0.4%	0.01	0.1%	0.01	1%					0.10	0.4%	0.6	0.3%
Large School	5.13	4%	0.21	4%							0.45	2%	5.8	3%
Medium School	3.90	3%	0.09	1%							0.25	1%	4.2	2%
Universities and Colleges	22.46	18%	1.15	20%					0.05	1%	1.45	6%	25.1	13%
Restaurant/Tavern	2.10	2%											2.1	1%
Warehouse/Wholesale	1.80	1%									0.11	0.4%	1.9	1%
Mixed Use	1.10	1%											1.1	1%
Small Commercial	28.70	23%	1.30	23%							11.40	44%	41.4	22%
Other Commercial Buildings													15.0	8%
Non-buildings													12.9	7%
Total	124.5	100%	5.8	100%	1.0	100%	1.6	100%	3.8	100%	26.0	100%	190.5	100%

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 6.10b: Achievable Savings by End Use for "Most Likely" Scenario in FY 2010/11, (GWh/yr.)*

Segment	End-use													
	Lighting		HVAC		Sp Heat, Cool and DHW		Refrigeration		Plug Load		Integrated Design - New		Total	
	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%
Large Office	78.08	21%	9.08	39%	1.92	45%			19.50	87%	13.96	13%	122.5	21%
Medium Office	18.83	5%	1.80	8%	0.34	8%			2.10	9%	4.32	4%	27.4	5%
Large Non-food Retail	62.10	17%	2.00	9%	1.36	32%					22.05	21%	87.5	15%
Medium Non-food Retail	13.50	4%	0.16	1%	0.18	4%					4.80	5%	18.6	3%
Food Retail	2.71	1%					5.70	100%			1.76	2%	10.2	2%
Large Hotel	5.20	1%	0.02	0.1%	0.06	1%					2.10	2%	7.4	1%
Medium Hotel/Motel	2.60	1%			0.12	3%					1.35	1%	4.1	1%
Hospital	12.00	3%	1.46	6%	0.20	5%			0.60	3%	1.05	1%	15.3	3%
Nursing Homes	1.00	0.3%	0.03	0.1%	0.06	1%					0.30	0.3%	1.4	0.2%
Large School	9.75	3%	1.03	4%							1.35	1%	12.1	2%
Medium School	7.41	2%	0.43	2%							0.75	1%	8.6	1%
Universities and Colleges	60.14	16%	4.60	20%					0.30	1%	4.35	4%	69.4	12%
Restaurant/Tavern	4.20	1%											4.2	1%
Warehouse/Wholesale	3.60	1%									0.77	1%	4.4	1%
Mixed Use	2.20	1%											2.2	0.4%
Small Commercial	86.10	23%	2.60	11%							45.60	44%	134.3	23%
Other Commercial Buildings													30.0	5%
Non-buildings													25.8	4%
Total	369.4	100%	23.2	100%	4.2	100%	5.7	100%	22.5	100%	104.5	100%	585.4	100%

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 6.10c: Achievable Savings by End Use for "Most Likely" Scenario in FY 2015/16, (GWh/yr.)*

Segment	End-use													
	Lighting		HVAC		Sp Heat, Cool and DHW		Refrigeration		Plug Load		Integrated Design - New		Total	
	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%
Large Office	143.64	21%	27.24	47%	3.84	45%			32.50	87%	27.92	13%	235.1	21%
Medium Office	34.61	5%	5.40	9%	0.68	8%			3.50	9%	8.64	4%	52.8	5%
Large Non-food Retail	144.90	21%	3.00	5%	2.72	32%					51.45	24%	202.1	18%
Medium Non-food Retail	31.50	5%	0.24	0.4%	0.36	4%					11.20	5%	43.3	4%
Food Retail	5.70	1%					11.60	100%			3.96	2%	21.3	2%
Large Hotel	10.40	2%	0.07	0.1%	0.12	1%					4.20	2%	14.8	1%
Medium Hotel/Motel	5.20	1%			0.24	3%					2.70	1%	8.1	1%
Hospital	14.40	2%	4.38	8%	0.40	5%			1.00	3%	2.45	1%	22.6	2%
Nursing Homes	2.00	0%	0.10	0.2%	0.12	1%					0.70	0.3%	2.9	0.3%
Large School	13.50	2%	3.09	5%							3.15	1%	19.7	2%
Medium School	10.26	2%	1.30	2%							1.75	1%	13.3	1%
Universities and Colleges	74.88	11%	9.20	16%					0.50	1%	10.15	5%	94.7	8%
Restaurant/Tavern	8.40	1%											8.4	1%
Warehouse/Wholesale	6.75	1%									1.65	1%	8.4	1%
Mixed Use	4.40	1%											4.4	0.4%
Small Commercial	172.20	25%	3.90	7%							88.00	40%	264.1	23%
Other Commercial Buildings													60.0	
Non-buildings													51.6	
Total	682.7	100%	57.9	100%	8.5	100%	11.6	100%	37.5	100%	217.9	100%	1127.7	90%

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 6.11a: Achievable Savings by End Use for "Upper" Scenario in FY 2005/06, (GWh/yr.)*

Segment	End-use													
	Lighting		HVAC		Sp Heat, Cool and DHW		Refrigeration		Plug Load		Integrated Design - New		Total	
	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%
Large Office	48.28	19%	4.54	35%	0.96	46%			6.50	87%	4.65	9%	64.9	16%
Medium Office	12.47	5%	0.90	7%	0.17	8%			0.70	9%	1.44	3%	15.7	4%
Large Non-food Retail	41.40	16%	1.00	8%	0.68	33%					14.70	27%	57.8	15%
Medium Non-food Retail	9.00	3%	0.08	1%	0.09	4%					3.20	6%	12.4	3%
Food Retail	1.91	1%					3.20	100%			0.44	1%	5.6	1%
Large Hotel	5.20	2%	0.012	0.1%	0.02	1%					0.70	1%	5.9	1%
Medium Hotel/Motel	2.60	1%			0.04	2%					0.45	1%	3.1	1%
Hospital	4.80	2%	0.73	6%	0.10	5%			0.20	3%	0.70	1%	6.5	2%
Nursing Homes	1.00	0.4%	0.02	0.1%	0.02	1%					0.20	0.4%	1.2	0.3%
Large School	6.38	2%	0.52	4%							0.90	2%	7.8	2%
Medium School	4.85	2%	0.22	2%							0.50	1%	5.6	1%
Universities and Colleges	27.31	10%	2.30	18%					0.10	1%	2.90	5%	32.6	8%
Restaurant/Tavern	4.20	2%											4.2	1%
Warehouse/Wholesale	2.70	1%									0.33	1%	3.0	1%
Mixed Use	2.20	1%											2.2	1%
Small Commercial	86.10	33%	2.60	20%							22.80	42%	111.5	28%
Other Commercial Buildings													30.0	8%
Non-buildings													25.8	7%
Total	260.4	100%	12.9	100%	2.1	100%	3.2	100%	7.5	100%	53.9	100%	395.8	100%

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 6.11b: Achievable Savings by End Use for "Upper" Scenario in FY 2010/11, (GWh/yr.)*

Segment	End-use													
	Lighting		HVAC		Sp Heat, Cool and DHW		Refrigeration		Plug Load		Integrated Design - New		Total	
	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%
Large Office	131.12	22%	27.24	46%	4.80	46%			39.00	87%	23.26	13%	225.4	22%
Medium Office	32.34	5%	5.40	9%	0.85	8%			4.20	9%	7.20	4%	50.0	5%
Large Non-food Retail	103.50	17%	3.50	6%	3.40	33%					44.10	24%	154.5	15%
Medium Non-food Retail	22.50	4%	0.28	0.5%	0.45	4%					9.60	5%	32.8	3%
Food Retail	4.21	1%					8.90	100%			3.30	2%	16.4	2%
Large Hotel	10.40	2%	0.07	0%	0.12	1%					3.50	2%	14.1	1%
Medium Hotel/Motel	5.20	1%			0.24	2%					2.25	1%	7.7	1%
Hospital	12.80	2%	4.38	7%	0.50	5%			1.20	3%	2.10	1%	21.0	2%
Nursing Homes	2.00	0.3%	0.10	0.2%	0.10	1%					0.60	0.3%	2.8	0.3%
Large School	11.00	2%	3.09	5%							2.70	1%	16.8	2%
Medium School	8.36	1%	1.30	2%							1.50	1%	11.2	1%
Universities and Colleges	64.99	11%	8.05	14%					0.60	1%	8.70	5%	82.3	8%
Restaurant/Tavern	8.40	1%											8.4	1%
Warehouse/Wholesale	5.18	1%									1.65	1%	6.8	1%
Mixed Use	4.40	1%											4.4	0.4%
Small Commercial	172.20	29%	5.20	9%							71.60	39%	249.0	25%
Other Commercial Buildings													60.0	6%
Non-buildings													51.6	5%
Total	**598.6**	**100%**	**58.6**	**100%**	**10.5**	**100%**	**8.9**	**100%**	**45.0**	**100%**	**182.1**	**100%**	**1015.2**	**100%**

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 6.11c: Achievable Savings by End Use for "Upper" Scenario in FY 2015/16, (GWh/yr.)*

Segment	End-use													
	Lighting		HVAC		Sp Heat, Cool and DHW		Refrigeration		Plug Load		Integrated Design - New		Total	
	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%	GWh/yr.	%
Large Office	195.49	23%	45.40	46%	8.64	46%			58.50	87%	46.53	12%	354.6	22%
Medium Office	48.78	6%	9.00	9%	1.53	8%			6.30	9%	14.39	4%	80.0	5%
Large Non-food Retail	165.60	19%	6.50	7%	6.12	32%					102.90	27%	281.1	17%
Medium Non-food Retail	36.00	4%	0.52	1%	0.81	4%					22.40	6%	59.7	4%
Food Retail	6.50	1%					20.80	100%			7.70	2%	35.0	2%
Large Hotel	15.60	2%	0.12	0.1%	0.26	1%					7.00	2%	23.0	1%
Medium Hotel/Motel	7.80	1%			0.52	3%					4.50	1%	12.8	1%
Hospital	16.00	2%	7.30	7%	0.90	5%			1.80	3%	4.90	1%	30.9	2%
Nursing Homes	3.00	0.3%	0.16	0.2%	0.20	1%					1.40	0.4%	4.8	0.3%
Large School	16.00	2%	5.15	5%							6.30	2%	27.5	2%
Medium School	12.16	1%	2.16	2%							3.50	1%	17.8	1%
Universities and Colleges	84.43	10%	16.10	16%					0.90	1%	20.30	5%	121.7	8%
Restaurant/Tavern	12.60	1%											12.6	1%
Warehouse/Wholesale	7.65	1%									3.30	1%	11.0	1%
Mixed Use	6.60	1%											6.6	0.4%
Small Commercial	229.60	27%	6.50	7%							136.80	36%	372.9	23%
Other Commercial Buildings													90.0	
Non-buildings													77.4	
Total	**863.8**	**100%**	**98.9**	**100%**	**19.0**	**100%**	**20.8**	**100%**	**67.5**	**100%**	**381.9**	**100%**	**1619.3**	**90%**

*Results are measured at the customer's point of use and do not include line losses.

7. DEMAND IMPACTS

7.1 INTRODUCTION

This section presents an assessment of the demand savings that would occur as a result of the electricity savings contained in each of the three preceding energy efficiency forecasts, namely:

- Economic Potential
- "Most Likely" Achievable Potential
- "Upper" Achievable Potential.

In each case, both energy and demand savings are defined relative to the Reference Case presented previously in Section 3. It should be emphasized that the CPR is not a demand reduction study, per se. Rather, the focus is on the demand impacts of the energy efficiency measures contained in the Economic and Achievable Potential forecasts. It is recognized that numerous other technologies and load control strategies could be used to reduce peak demand requirements. These latter technologies and strategies are beyond the scope of this study.

The discussion in this section is organized as follows:

- Overview of BC Hydro System Load Profiles
- BC Hydro Annual Demand Periods Used in This CPR
- Derivation of Demand Impacts
- Presentation of Results.

7.2 OVERVIEW OF BC HYDRO SYSTEM LOAD PROFILES

Exhibit 7.1 shows BC Hydro load profiles, at the level of both total system and individual sector, for an average winter weekday. The winter period of December and January is when BC Hydro typically experiences its highest levels of electricity demand and, therefore, is the primary focus of this study. As illustrated in Exhibit 7.1, total system peak demand is approximately 8,000 MW[89,90] on an average winter day. It can also be seen in Exhibit 7.1 that the weekday load increases during the 16-hour period from 6 a.m. to 10 p.m.

The commercial sector, which is the focus of this section, accounts for about 2,200 MW, or 27% of the total system load on a typical winter weekday.

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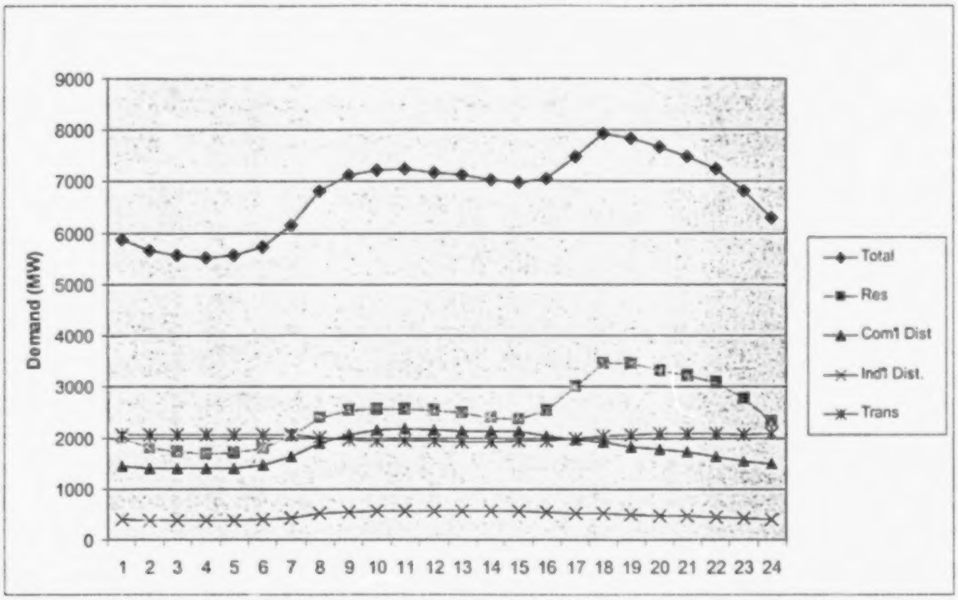
[89] The load profiles presented in this section were derived to be representative of typical daily winter loads within the different regions and sectors of BC Hydro's service area and include line losses. At this disaggregated level data have been approximated using a sample of metered sites that are assumed to characterize the sectors involved. Actual metered data are not available at this level. These load profiles are intended for use only in the context of this study.

[90] BC Hydro's winter system peak is close to 9,000 MW; 8,000 MW is intended to represent a "typical" winter day.

Exhibit 7.1: Average Winter Weekday Load Profile for Total BC Hydro System



Exhibits 7.2 and 7.3 present further details on the commercial sector average winter load profile, including a break out by service region. Exhibit 7.2 shows that the shape of the daily commercial load profiles is similar in each of the three service regions, with the Lower Mainland accounting for slightly more than 50% of the total.

Exhibit 7.2: Average Winter Weekday Load Profile for Commercial Sector

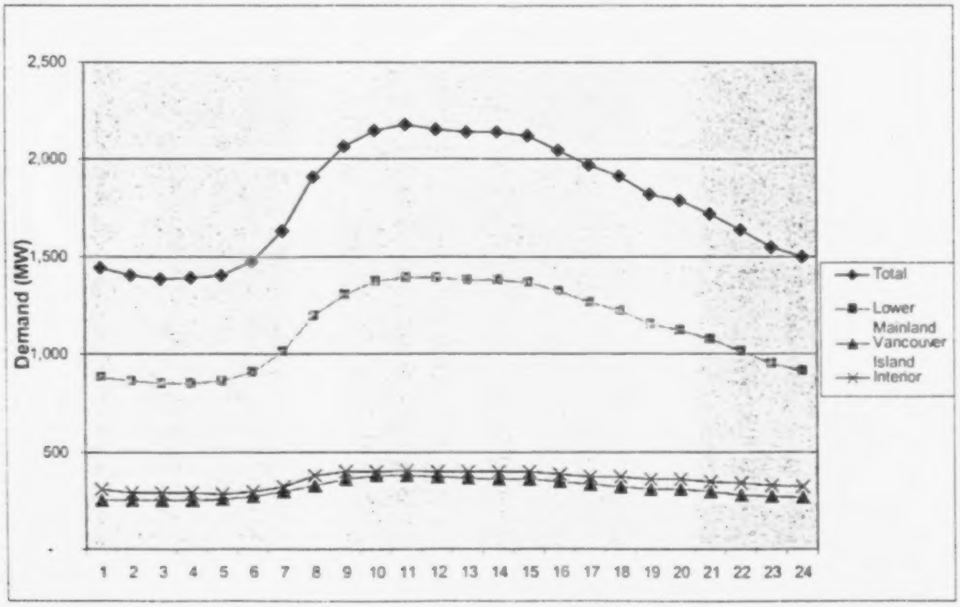


Exhibit 7.3 shows that the ratio of "average" 16-hour weekday demand to "maximum" demand is approximately 90% for the total commercial sector. This ratio illustrates that the commercial sector demand is "relatively flat" on a typical winter weekday.

Exhibit 7.3: Comparison of "16-hour Average" and "Peak" Demand for the Commercial Sector

Average Winter Day	Total BCH Commercial	Lower Mainland	Vancouver Island	Interior
Maximum Peak Demand—Commercial Sector (MW)	2,176	1,394	377	406
Av. 16-hr. Peak, Weekday 6 a.m. to 10 p.m. (MW)	1,961	1,249	336	376
Ratio: Average Peak/Maximum Peak (%)	90.2	89.6	89.1	92.6

7.3 BC HYDRO ANNUAL DEMAND PERIODS USED IN THIS CPR

Three demand periods were defined for this CPR, as shown in Exhibit 7.4. The period selected for this CPR is weekdays from 6 a.m. to 10 p.m. during the months of December and January (referred to as the Winter, On-peak). Weekends and the hours from 10 p.m. to 6 a.m. during the months of December and January are off-peak (referred to as the Winter, Off-peak). The remaining hours of the year are considered to also be off-peak and are referred to as the Shoulder period. The same demand period definitions apply to each of the three service regions: Lower Mainland, Vancouver Island and the Interior.

Exhibit 7.4: BC Hydro Annual Demand Periods for CPR 2002

Period	Months	Days	Hours	Annual Total	
				Hours	%
Winter, On-peak	December 1 to January 31	Monday to Friday, inclusive	6 a.m. to 10 p.m.	709	8.1
Winter, Off-peak	December 1 to January 31	Monday to Friday	10 p.m. to 6 a.m.	779	8.9
		Saturday, Sunday	All hours		
Shoulder	February 1 to November 30	All days	All hours	7272	83
Total				**8,760**	**100**

7.4 DERIVATION OF DEMAND IMPACTS

The CPR analysis to this point in the study has been focused exclusively on electricity savings. The following discussion outlines the methodology employed to derive demand impacts from the electricity values. (For additional detailed data, *see* Appendix I.)

The steps used to derive the demand impacts from the electricity consumption values contained in the three Potential estimates are listed below and discussed in the following paragraphs. They were:

- Annual electricity use in the base year was distributed among the three demand periods, by building segment and end use.
- Using the above data, average winter on-peak demand was calculated for the base year and compared with available utility data.
- The base year electricity use distributions were applied to each of the Reference Case milestones to derive average winter on-peak demand estimates for each period.
- The above process was repeated for the Economic Potential Forecast with emphasis on changes in electricity usage patterns that occur due to the technologies or measures that were introduced in this forecast. Average winter on-peak demand estimates for each period in the Economic Potential Forecast were derived.
- Average winter on-peak demand savings were calculated as the difference between the Economic Potential and Reference Forecasts.
- The on-peak electricity-to-demand ratios calculated for the base year Economic Potential forecast were applied to the savings contained in the Achievable Potential scenarios.

Further discussion of each step is provided below.

7.4.1 Distribute Annual Base Year Electricity Use

Exhibit 7.5 provides a sample distribution of annual electricity use among the three BC Hydro demand periods. The distribution shown in Exhibit 7.5 is organized by end use and is for large offices in the Lower Mainland.

Exhibit 7.5: Sample Distribution of Annual Electricity Use by Demand Period for Large Offices in Lower Mainland

End-use	Annual Electricity Distribution			
	Winter On-peak (%)	Winter Off-peak (%)	Shoulder (%)	Total (%)
Large Office				
General Lighting	12%	5%	83%	100%
Architectural Lighting	9%	8%	83%	100%
Other Lighting	12%	5%	83%	100%
Office Equip. & Plug Loads	12%	5%	83%	100%
Commercial Food Service	8%	9%	83%	100%
Commercial Refrigeration	8%	9%	83%	100%
Miscellaneous (Elev, Ext. Lghts)	11%	6%	83%	100%
Electric Space Heat	18%	28%	54%	100%
Space Cooling	2%	1%	97%	100%
Electric DHW	13%	8%	79%	100%
HVAC Equipment (Fans & Pumps)	10%	7%	83%	100%

Two tasks are required to generate the data shown in Exhibit 7.5. They are:

- Distribute annual end-use electricity consumption between the December–January period and the remaining 10 months of the year.
- Allocate the December–January electricity consumption between the winter on- and off-peak periods.

The "general lighting" end use is used to demonstrate the approach used to generate the data shown in Exhibit 7.5.

- The first task was to determine the proportion of annual general lighting electricity consumption that typically occurs during the winter peak months of December and January versus the remaining 10 "shoulder" months of the year. Detailed commercial sector end-use load-profile data were not available from BC Hydro. Consequently, the values employed are estimated values based on the data contained in the detailed building profiles.[91] In this case, it was assumed that general lighting hours of operation are relatively evenly distributed throughout the year. The winter period of December 1 to January 31, inclusive, accounts for approximately 17% of the annual hours; therefore, as illustrated in Exhibit 7.5, 17% of total annual general lighting electricity use was allocated to the winter period of December and January (Winter On- and Off- peak). The other 83% of general lighting annual electricity use was allocated to the remaining 10 months of the year (the Shoulder period).

- Once annual general lighting electricity use was distributed between winter and shoulder demand periods, the next task was to allocate the winter portion (i.e., the 17%) between the on-peak and off-peak periods. As in the preceding task, the distribution between winter "on-peak" and winter "off-peak" drew on the same data sets that were used to generate the CEAAM building profiles. In this case, a disproportionate share of general lighting use occurs during the on-peak period as the on-peak period coincides very closely with the peak building occupancy and lighting use period. As a result, the estimated distribution of general lighting was 12% during winter on-peak period and 5% during the winter off-peak period.

The above process was applied to each of the remaining end uses and building segments. As illustrated in Exhibit 7.5, with the exception of space heating and cooling, annual electricity consumption in the remaining end uses[92] in the large office segment was assumed to be relatively evenly distributed throughout the year. However, as illustrated in Exhibit 7.5, there is greater end-use variation in the distribution of electricity use between the winter on- and off-peak demand periods. The distribution of electricity use between these two periods reflects the following considerations:

- Architectural lighting has a more even distribution between "on-peak" and "off-peak" due to the security lighting in corridors, stairways and lobbies.

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[91] These are the Building Profiles presented previously in Section 3 that have been constructed using the CEEAM building energy use simulation model.

[92] DHW is an interesting exception; although usage patterns remain relatively constant, electricity requirements increase because the temperature of the source water is lower in this period.

- Non-lighting and non-HVAC loads were evenly distributed between "on-peak" and "off-peak" periods.
- Miscellaneous equipment, which includes vertical transportation (elevators), was biased towards the "on-peak" period when elevators typically operate.
- Finally, HVAC equipment is biased towards the "on-peak" period, although some equipment such as pumps operates during the "off-peak" period as well as a portion of ventilation systems.

Further discussion of the assumptions employed to generate the space heating and cooling distributions is provided below.

❑ Space Heating

The distribution of space heating electricity consumption relied on degree-day data to split the electricity use between the "peak" and shoulder months.

- For large high-rise buildings, including large and medium offices as well as large and medium hotels, 46% of the heating electricity was allocated to the "peak" period. This was based on the monthly degree-day data at a 50 °F base (building balance point assumed to be at 50 °F or lower).
- For large low-rise buildings and hospitals, 40% of the heating electricity was allocated to the peak period based on monthly degree-day data at 55 °F (building balance point for these buildings assumed to be in the 55 °F range)

The split between "on-peak" and "off-peak" was assumed to be biased towards the off-peak period based on hours (709 versus 779 hours in the "off-peak") and the higher heating load required during the unoccupied period due to the reduced internal heat gains (no occupants, lower lighting loads).

❑ Space Cooling

Virtually all the space cooling electricity use was assumed to occur during the 10 shoulder months. However, approximately 3% of annual use was assumed to occur in the December–January period. This recognizes that:

- Some building segments, such as large retail and hotels, require mechanical cooling during the winter months.
- Large and medium offices that use floor-by-floor compartmental air handling units also use some mechanical cooling, even in winter months.

The split between on- and off-peak was biased towards on-peak due to the typical equipment operating patterns.

7.4.2 Calculate Base Year Average On-peak Demand

Once the preceding steps were completed the total amount of electricity consumption in the winter on-peak period was calculated. Given that the total number of hours for the on-peak period is also known (i.e., 709 hours), it is also possible to calculate the average demand for each end use during the on-peak period using the formula below.

$$\text{Average end-use ``on-peak'' demand} = \frac{\text{Total end-use electricity use * On-peak \%}}{\text{Hours in ``on-peak'' period}} \text{ x } (1 + \text{line losses})$$

The above calculation was repeated for each combination of building segment and end use and aggregated to obtain a total commercial demand for each service region. Because the calculation begins with actual electricity use in the period, diversity is accounted for. Similarly, as the electricity savings are calculated at the customer level, line losses need to also be added in. In this case, line losses of 7% were used[93].

Exhibit 7.6 shows a sample calculation of average on-peak demand for large offices in Lower Mainland.

Exhibit 7.6: Sample Calculation of "Average On-peak Demand" for Large Offices in Lower Mainland, (MW)*

End-use	Annual Electricity Distribution (%)				Peak:Avg Ratio	Annual Electricity Use, Reference Case, (GWh/yr.)				Average Demand in Winter On-peak (MW)			
	Winter On peak	Winter Off peak	Shoulder	Total (check)		2000	2005	2010	2015	2000	2005	2010	2015
Large Office													
General Lighting	12%	5%	83%	100%	1.000	380	397	413	423	68.8	72.0	74.7	76.6
Architectural Lighting	9%	8%	83%	100%	1.000	52	55	58	61	7.1	7.4	7.8	8.2
Other Lighting	12%	5%	83%	100%	1.000					0.0	0.0	0.0	0.0
Office Equip. & Plug Loads	12%	5%	83%	100%	1.000	197	222	266	309	35.6	40.3	48.1	55.9
Commercial Food Service	8%	9%	83%	100%	1.000	4	5	6	6	0.5	0.6	0.7	0.7
Commercial Refrigeration	8%	9%	83%	100%	1.000	4	5	6	6	0.5	0.6	0.7	0.7
Miscellaneous (Elev, Ext. Lghts)	11%	6%	83%	100%	1.000	179	200	228	254	29.7	33.2	37.9	42.2
Electric Space Heat	18%	28%	54%	100%	1.000	10	11	12	13	2.8	3.0	3.2	3.5
Space Cooling	2%	1%	97%	100%	1.000	55	61	69	76	1.7	1.8	2.1	2.3
Electric DHW	13%	8%	79%	100%	1.000	9	10	11	12	1.8	2.0	2.2	2.4
HVAC Equipment (Fans & Pumps)	10%	7%	83%	100%	1.000	218	236	260	283	33.0	35.6	39.3	42.7
Total					**1.000**					**181.6**	**196.5**	**216.7**	**235.4**

* Includes lines losses @ 7%. "On-peak" is weekdays from 6 a.m. to 10 p.m. during the months of December and January.

The calculated results for the base year were compared with BC Hydro's estimated data; the calculated results were within 1% of the BC Hydro values. As the BC Hydro values shown earlier in this section were intended to be "indicative" for a "typical" day rather than a direct calibration with the CPR data, the results were considered to be in good agreement and no further reconciliation was carried out.

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[93] This consists of 3% area transmission and 4% distribution losses and is the same value used as in previous portions of the study. The 7% value omits bulk transmission losses of 5%; however, this is consistent with the approach being applied to other possible electricity options, such as small-scale renewable electricity. It is also consistent with the general assumption that the most likely future electricity supply options will occur at the regional levels rather that at remote sites, such as the historical large-scale hydroelectric developments.

7.4.3 Calculate Average On-peak Demand for Remaining Reference Forecast Years

The same electricity end-use distribution percentages employed in the base year were then applied to each of the milestone periods in the Reference Case. The results are shown in the next subsection.

7.4.4 Calculate Average On-peak Demand for Economic Potential Forecast

Average winter on-peak demand for the Economic Potential Forecast was calculated exactly as outlined above for the Reference Case. In most cases the end-use distributions of annual electricity consumption remained the same as in the Reference Case; however, some of the technologies introduced in the Economic Potential Forecast involve both reduced annual electricity use and a change in the time of use. For example, the Reference Case assumes that a large portion of the HVAC equipment operates even during periods when the buildings are not occupied. However, the Economic Potential Forecast achieves electricity savings, in part, by turning equipment off during periods of non-occupancy. This means that while electricity consumption is reduced, the distribution between on- and off-peak periods is also affected. This adjustment was applied to the HVAC equipment.

The results are shown in the next subsection. (For additional details, *see* Appendix I.)

7.4.5 Calculate Average On-peak Demand Savings for Economic Potential Forecast

Average winter on-peak demand savings were calculated as the difference between the Economic Potential and Reference Forecasts. The results are shown in the next subsection. (For additional details, *see* Appendix I.)

7.4.6 Calculate Average On-peak Demand Savings for Achievable Potential Scenarios

The electricity end-use distributions employed in the Economic Potential Forecast were applied to the electricity savings in the Achievable Potential scenarios. The results are shown in the next subsection. (For additional details, *see* Appendix I.)

7.5 PRESENTATION OF RESULTS

This section presents the estimated demand savings in two exhibits:

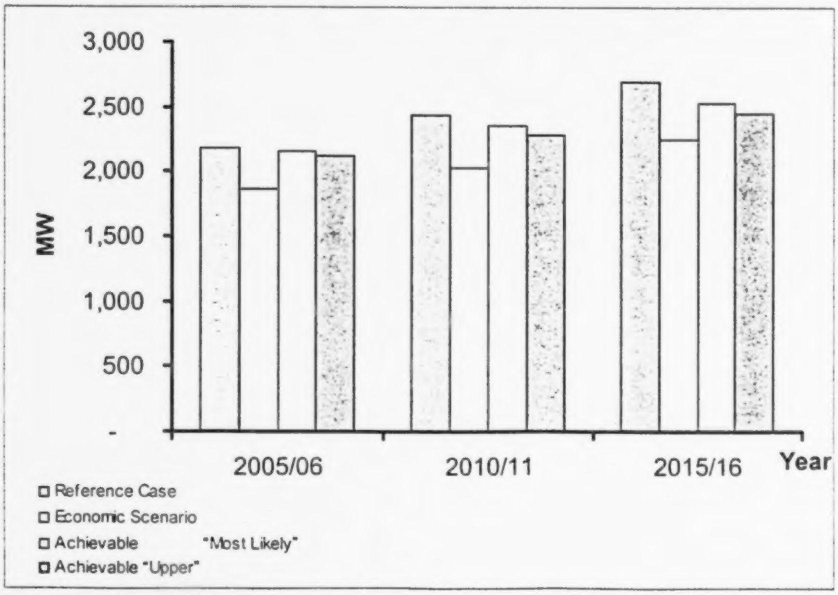
- Exhibit 7.7 compares the average on-peak demand estimates for the Reference Case and the Economic Potential and Achievable Potential Forecasts, including the demand savings. The results are presented for each milestone year and service region as well as for the total BC Hydro system.
- Exhibit 7.8 shows a summary of the average on-peak demand for each scenario.

Exhibit 7.7: On-peak Demand Savings for Economic and Achievable Forecasts versus Reference Case by Service Region and Milestone Year for the Commercial Sector, (MW)*

Service Region	Milestone Year	Average On-peak Demand Reference Case	On-peak Demand Savings					
			Economic		Achievable "Most Likely"		Achievable "Upper"	
			MW	%	MW	%	MW	%
Total BC Hydro	Base Year	1,961						
	2005/06	2,180	314	14%	29	1%	60	3%
	2010/11	2,438	408	17%	88	4%	153	6%
	2015/16	2,699	450	17%	172	6%	247	9%
Lower Mainland	Base Year	1,290						
	2005/06	1,442	211	15%	19	1%	40	3%
	2010/11	1,622	286	18%	58	4%	102	6%
	2015/16	1,806	318	18%	115	6%	165	9%
Vancouver Island	Base Year	327						
	2005/06	358	49	14%	5	1%	10	3%
	2010/11	394	61	15%	14	4%	25	6%
	2015/16	430	66	15%	27	6%	39	9%
Interior	Base Year	343						
	2005/06	380	54	14%	5	1%	10	3%
	2010/11	422	61	15%	15	4%	26	6%
	2015/16	463	66	14%	30	6%	42	9%

* Includes lines losses @ 7%. "On-peak" is weekdays from 6 a.m. to 10 p.m. during the months of December and January.

Exhibit 7.8: Average On-peak* Demand by Scenario and Milestone Year for Total BC Hydro Service Area in the Commercial Sector, (MW)



*"On-peak" is weekdays from 6 a.m. to 10 p.m. during the months of December and January.

8. ADDITIONAL TECHNOLOGIES

8.1 INTRODUCTION

In the introductory section to this report, Exhibit 1.1 presented the full range of technologies that were identified by the study team for consideration. The introduction also noted that technologies shown in Exhibit 1.1 were organized into two groups:

- ***Electrical-efficient technologies that are commercially available today, or will be available by 2005.*** These technologies are the primary focus of this study.

- ***Electrical-efficient technologies that are not commercially available today but are expected to become available after 2005 but before the end of the study period.*** These emerging technologies have not been included in the study results but they are addressed in a qualitative manner in this section.

In addition, it is noted in the introductory section that numerous other technologies could contribute to B.C.'s electricity future but are not included in this study as they are outside the agreed scope. For example, technologies such as advanced two-way thermostats and thermal energy storage provide an opportunity to reduce peak demand; however, consideration of specific load control technologies was outside the scope of this study. Similarly, technologies such as district cooling for large buildings using seawater or solar heating (e.g., Solarwall) can also result in reduced energy use. However, they also are not included, in part, because their energy contribution and cost is much more site specific and, in part, because they represent alternate energy sources. The exclusion of both groups of technologies does not imply any judgment on their potential contribution—only that the limits of time and resources required that this study limit its focus to those technologies that met the selection criteria noted above.[94]

Based on client discussions held in the early stages of the study, the following emerging technologies were selected for review:

- Two-photon lamp
- Aeorgel glazings
- Advanced refrigeration technologies:
  - Magnetic refrigeration
  - Thermo-acoustic refrigeration
  - Linear compressors.

The remainder of this section provides a brief discussion of the above technologies. In each case the discussion provides a brief description of the technology, including: its current development status and forecast dates for commercial introduction; an estimate of its electrical efficiency improvements over conventional technology; and, an estimate of its potential CPR impacts (e.g., how significant are the potential additional electricity savings?)

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[94] It is also recognized that additional technologies, not currently envisioned, may emerge over the study period that will provide further opportunities for electrical efficiency.

8.2 TWO-PHOTON LAMP

8.2.1 Technology Description

Fluorescent lighting systems employing lamps with two-photon phosphors (two visible per one ultraviolet) have been discussed as a concept for more than a decade; however, the U.S. DOE has now included them in their most recent lighting "Technology Roadmap" as a intermediate target technology. If this target date is to be met, then early commercial availability would be expected in the next 5 to 10 years. This technology, which consists of new phosphor materials, electrode materials and ballast designs, promises to increase lighting efficacy levels into the range of 180 to 230 lumens/watt, which is about twice the levels currently available.

8.2.2 Potential CPR Impacts

Due to the dominance of lighting electricity use in the commercial sector and the magnitude of the savings provided over current technology, the market availability of the two-photon lamp systems could provide significant additional potential electricity savings.

8.3 AEROGEL GLAZINGS

8.3.1 Technology Description

Aerogel is a transparent material that looks like glass, insulates better than mineral wool and is more heat resistant than aluminum making it suitable for use in many potential applications, including as a double pane window fill. Aerogel is one of the few existing materials that is both transparent and porous. It can be formed into almost any useful shape and can be inexpensively manufactured.

There are a number of companies in the US currently working on developing this technology for different applications. They include Nanopore, Aspen Systems, Ocellus, Cabot Corp., and the TASSI Company. Use of aerogel for windows will not be possible until researchers find a way to clear them of their slightly hazy blue appearance.

Silica aerogel as a double pane window fill performs to R-20 in a 90% vacuum, in contrast with today's best performance of around R-6[95]. In the commercial sector, the higher thermal performance provided by the aerogel glazings would result in significantly lower heating and cooling loads with consequent reductions in heating and cooling energy use.

8.3.2 Potential CPR Impacts of Aerogel Glazings

Aerogel glazings could provide substantial heating and cooling load reductions. However, these end uses account for approximately 6% of current commercial sector electricity use in British Columbia. Consequently, their potential overall impact on the electricity savings presented in the preceding sections would be modest. This modest potential impact on electricity savings is due to the combination of relatively low cooling loads in British Columbia and low fuel share for electric space heating in the commercial sector.

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[95] '*Aerogel: Electricity Efficient Material for Buildings*', Center for Building Science News, LBL, 1995.

8.4 ADVANCED REFRIGERATION TECHNOLOGIES

This category includes three emerging refrigeration technologies as follows:

- Magnetic refrigeration
- Thermo-acoustic refrigeration
- Linear compressors

8.4.1 Magnetic Refrigeration

Compounds of gadolinium, silicon and germanium have been found to heat up when magnetized and cool down when removed from a magnetic field. This effect can be large enough to produce a practical cooling effect. Magnetic refrigeration has the potential to produce higher efficiencies than conventional vapour compression cycles without using harmful HFCs or CFCs. Of many potential uses for this new technology, the most promising are for refrigeration/freezing and air conditioning. It may also eventually be used in producing cheap liquid hydrogen as a future fuel source.

Magnetic refrigeration is currently still in the prototype stage, with research being conducted by the Ames laboratory and the Astronautics Technology Center. It will take from 5 to 10 years to move magnetic refrigeration to the marketplace, where it will likely find it's niche with large supermarket chains, shopping malls and food storage warehouses. Its use in home refrigerators and air conditioners is still 20 years down the road.

The first prototype achieved a cooling power of 600 watts with an impressive COP of 15 using a powerful superconducting magnet. Initial design studies indicate that household magnetic fridge/freezers (which would use less powerful magnets) could have a COP of 3 with a total cooling of 120 watts. Magnetic refrigeration is about 20% more energy efficient than traditional cooling systems, so although it may initially cost more, consumers would earn back the difference in electricity savings within 5 years.[96] In practical terms, a typical 18-cu. ft. refrigerator today uses about 680 kWh/yr. whereas a new magnetic refrigerator may be able to perform at around 540 kWh/yr. Although the initial prototypes and research are focusing on small appliance–type applications, similar savings for commercial fridges and freezers are also possible. In addition, the technology can be extended to air conditioning applications (high-temperature refrigeration) for small, commercial, packaged equipment.

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[96] ASHRAE Journal, Industry News, *Magnetic Refrigeration*, January 2002.

8.4.2 Thermo-Acoustic Refrigeration

Thermo-acoustic refrigeration employs acoustic power to pump heat. An acoustic driver generates a standing wave that creates a linear temperature gradient within densely packed parallel plates. This temperature gradient is caused by an irreversible transfer of heat between the working fluid, which is a noble gas, and the stack plates. The simplicity of thermo-acoustic devices could lead to refrigerators and cooling systems with low manufacturing and maintenance costs and new kinds of air-conditioning systems.

Prototypes have been made, but more research is needed to improve the performance of the heat exchangers used in the system. Research is currently underway at Johns Hopkins University and Purdue University. A home appliance based on thermo-acoustic refrigeration is still years away.

Performance calculations for thermo-acoustic refrigerators predict Coefficients of Performance (COPs) in the order of 40 to 50% of the ideal Carnot cycle, compared with the maximum COP achieved in devices built so far being only 20% of Carnot's cycle. One reason for the discrepancy between the theory and practical devices is the poor performance of the heat exchangers.[97] This would mean that a typical 18-cu. ft. refrigerator, which currently uses 680 kWh/yr., may actually use less than 340 kWh/yr. using this technology. As with magnetic refrigeration, this emerging technology has so far focused on small residential type prototypes. However, the technology can be extended to larger demand equipment used in commercial air conditioning and refrigeration applications.

8.4.3 Linear Compressors

A linear motor/compressor can replace the standard rotating motor/compressor as the prime mover in a conventional Rankine cycle refrigerator. It is compatible with CFC or non-CFC working fluids, requires no lubricant and maintains a higher electrical efficiency than any existing rotating motor/compressor commercially available today.

LG Electronics from Korea announced that it had successfully tested a linear compressor in a 24-cu. ft. commercial refrigerator at the 2000 Appliance Manufacturer Conference and Expo. LGE is now testing these refrigerators in the field, initially in Korea but eventually all around the world. Sunpower has also indicated that they could mass-produce linear machines at about the same cost as conventional machines, however more experience with large-scale production will be needed to confirm this claim.

LG Electronics' refrigerator, which used a linear compressor, reduced electricity consumption by 47% compared to the baseline model with a reciprocating compressor. Much of the electricity savings is realized by virtue of the fact that a linear compressor does not require a crank mechanism to convert rotary motion into reciprocating motion. The latter can account for up to half the friction loss in a standard system.[98] In practical terms, this means that annual consumption can be around 360 kWh/yr. as compared to the current 680 kWh/yr. for a typical 18-cu. ft. residential refrigerator. As with the previous refrigeration technologies, this emerging technology has so far focused on small residential-type prototypes. However, the technology could be extended to larger demand equipment used in commercial air conditioning and refrigeration applications.

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[97] www.me.jhu.edu/~htl/research/thermoacoustic/thermoacoustic.htm

[98] www.ammagazine.com

8.4.4 Potential CPR Impacts of Advanced Refrigeration Technologies

The impact of these refrigeration emerging technologies would be modest given that space cooling and commercial refrigeration represent an estimated 9% of the total commercial electricity use in the base year.

9. SUMMARY OF FINDINGS

The study findings confirm the existence of significant potential cost-effective electrical efficiency improvements in B.C.'s commercial sector. In the "most likely" and "upper" achievable scenarios, those electrical efficiency improvements would provide between 1,100 and 1,600 GWh/yr. of electricity savings by FY 2015/16 as well as on-peak demand savings of approximately 170 to 250 MW.

Within the priority large building segments that were subject to detailed modelling, savings potential is particularly significant in the office and retail segments, followed by universities/colleges. Potential savings in the small commercial building segment are also large; however, it is recognized that large number of facilities tend to increase program transactions costs and, as a result, achieving the potential savings in this segment may be more difficult than in the large building segments.

Lighting, more-efficient HVAC systems and new high-performance buildings account for nearly 60% of the identified Achievable Savings potential and an even larger share of the identified Economic Savings potential. Lighting provides a particularly significant opportunity due to three factors: T12 fluorescent lighting persists in some segments that can be replaced by efficient second-generation T8 electronic systems; lighting levels remain high in some segments such as existing offices; and, lighting use during unoccupied hours can be minimized.

Note: As in any study of this type, the results presented in this report are based on a number of important assumptions. Assumptions such as those related to the current penetration of efficient technologies and the rate of future growth in the stock of commercial buildings are particularly influential. Wherever possible, the assumptions used in this study are consistent with those used by BC Hydro. However, the reader is referred to a number of caveats throughout the main text of the report.

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11. GLOSSARY OF TERMS

(NOTE: underlined expressions are defined in this glossary.)

achievable potential:
The portion of savings identified in the economic potential that could realistically be achieved within the study period.

avoided cost:
The unit cost of acquiring the next resource to meet demand, which is used as a measure for evaluating individual demand- and supply-side options.

BC Hydro service area:
The portion of the Province of B.C. that receives retail electricity service from BC Hydro. The service region excludes the area served by Aquila Networks Canada (previously known as West Kootenay Power and Utilicorp Networks Canada) and, for the purpose of this study, includes the city of New Westminister. Approximately 75% to 80% of B.C.'s demand for electricity is in the BC Hydro service region and is supplied by BC Hydro.

co-generation:
The simultaneous production of electric or mechanical energy and useful heat energy from a single fuel source; for example, several mills in the B.C. forest sector co-generate electricity and process steam from wood waste for use in a pulping process.

cost of conserved energy (CCE):
The annualized unit energy cost of a DSM measure used to determine its cost effectiveness compared to additional electricity supply (as part of the Total Resource Cost Test). It is calculated as the annualized incremental cost (including annual O&M) of the DSM upgrade measure divided by the annual savings achieved, excluding any administrative or program costs to achieve full use of the technology or measure.

demand impacts:
In the context of the Conservation Potential Review 2002, this term refers to the average load reduction over the 6 a.m. to 10 p.m. period during an average weekday in December and January that is anticipated to result from the various electricity-saving technologies, programs or actions presented in the CPR 2002.

demand-side management (DSM):
Actions that modify customer demand for electricity and that can defer the need for new energy and capacity additions.

diversity
A relative measure of the likelihood that a series of connected loads will reach peak demand at the same time. A **high diversity** implies that individual connected loads will reach their peak demand at different times whereas a **low diversity** implies that they will reach peak demand at the same time.

economic efficiency:
Allocation of human and natural resources in a way that results in the greatest net economic benefit, regardless of how benefits and costs are distributed within society.

economic potential:
An estimate of the reduction of electricity consumption, relative to the reference case, that would occur if all electricity-consuming equipment were upgraded to the efficiency level that is cost-effective as calculated using the cost of conserved energy (CCE).

electric capacity:
The maximum electric power that a device or system is capable of producing or transferring. Electric capacity is measured in watts, kilowatts, megawatts etc.

electric energy:
It is the cumulative amount of electricity produced or consumed over a period of time. Electric energy is measured in kilowatt hours or gigawatt hours.

electric power:
The instantaneous rate that electric energy is produced, transmitted or consumed. Electric power is measured in watts, kilowatts, megawatts, etc.

electrical efficiency:
The ratio of the useful energy delivered by a system or end-use to the amount of electric energy supplied to it. This ratio measures how well electric energy is translated into another useful form of energy.

electrical intensity:
The ratio of electric energy consumed per application or end-use; for example, kilowatt hours per square metre of lit office space per day or kilowatt hours per tonne of aluminum produced. All else being equal, electrical intensity increases as electrical efficiency decreases.

electricity conservation:
Activities by electricity users that result in a reduction of the electric energy used to provide electric energy services. Electricity conservation can include a wide variety of behavioural or operational changes that result in energy savings. For the purpose of this study only, energy savings achieved through hard-wired or hardware installations are included.

emerging technologies:
New energy-conserving technologies that are expected to be market-ready in any of the years up to and including 2015. This category includes technologies that could be accelerated into the market during that period through targeted financial or technical support.

end-use:
Recognition of the fact that electric energy is of no value to a user without first being transformed, by a piece of equipment, into a service of economic value. For example, office lighting is an end-use, whereas electricity sold to the office tenant is of no value without the equipment (light fixtures, wiring, etc.) needed to convert the electricity into visible light. End-use is often used interchangeably with energy service.

energy service:
An amenity or service supplied jointly by energy and other components/equipment such as buildings, motors and lights. Examples of energy services include residential space heating, commercial refrigeration, aluminum smelting and public transit. The same energy service can frequently be supplied with different mixes of equipment and energy.

financial incentive:
Certain financial features in the utility's demand-side management programs designed to motivate customer participation. They may include features designed to reduce a customer's net cash outlay, pay-back period or cost of finance to participate.

fuel substitution:
The ability to use a different fuel to produce the same energy service; for example, natural gas can be used for space heating instead of electricity.

gigawatt hour (GWh):
One million kilowatt hours.

independent power producer (IPP):
A privately owned electricity-generating facility that is usually connected to a utility's transmission system to sell electricity.

kilowatt (kW):
One thousand watts; a basic unit of measurement of electric power. The amount of energy transferred at a rate of one kilowatt for one hour is a kilowatt hour.

kilowatt hour (kWh):
The basic unit of measurement of electric energy. One kilowatt hour represents the power of one thousand watts for a period of one hour. A typical non-electrically heated home in B.C. uses about 10,000 kWh per year.

load:
The amount of electricity required by a device, customer or group of customers as measured by an electricity meter.

load displacement:
The reduction of electricity requirements from existing utility customers through electricity conservation or through customer self-generation.

load factor:
The ratio of the average load supplied during a given period to the maximum load occurring during the same period.

load forecast:
An estimate of expected electricity requirements that have to be met by the electrical system in future years.

load shape:
The variation in electrical load over time, usually hour-by-hour. A load shape can be for the system, a customer or an end-use load over a set period such as a day or a year.

load shifting:
Utility DSM program to move electricity consumption from one period to another, most often from periods of high consumption to periods of low consumption (i.e., from on- to off-peak).

megawatt (MW):
One thousand kilowatts.

natural change in electrical intensity:
The future change in electrical intensity that is expected to occur in the absence of utility demand-side management programs. In developing an estimate of natural change in electrical intensity, it is necessary to make an explicit assumption about the future prices of electricity and competing fuels.

peak demand:
The maximum electric power required by a customer, device or system during a specified period (e.g., day, month, year).

peak clipping:
Utility DSM program used to reduce peak demand, without reducing demand at other times of the day or year.

Power Smart:
BC Hydro's demand-side management initiative, originally launched in 1989. Power Smart includes a full range of DSM programs aimed at BC Hydro's residential, commercial and industrial customers.

rate:
Generically refers to a utility's rate structure. **Average rate** specifically refers here to the overall average revenue per kilowatt hour that the utility receives from a given class of customers (e.g. residential) covered by one or more tariffs.

rate structure:
The formulae used by a utility to calculate charges for the use of electricity. For example, the present BC Hydro rate structure for residential customers consists of a basic monthly charge plus charges for the amount of electric energy used (i.e., cents/kWh). Other BC Hydro rate structures charge for energy at a rate per kilowatt hour that depends on the level of consumption, whereas others may include charges for peak demand.

reference case:
An estimate of the expected level of electricity consumption that would occur over the study period in the absence of any new Power Smart initiatives subsequent to FY 2000/01.

resource planning:
The process of long-term planning of electricity generation and transmission facilities to reliably meet the forecast requirements of BC Hydro's domestic customers. It addresses regional supply requirements and can utilize both supply- and demand-side resources while recognizing economic, environmental and social impacts and risks.

Resource Smart:
The name given to BC Hydro's strategy of improvements to existing power generation and transmission facilities to achieve supply-side efficiency through physical and operational modifications.

sector:
A group of customers having a common type of economic activity. BC Hydro divides its customers into three principal sectors: residential, commercial and industrial. Sectors are often divided into subsectors. For example, "offices" is a subsector of the commercial sector.

self-generation:
Generation of electricity by an industry or commercial enterprise whose principal product is not electricity. Self-generation can either reduce the amount of electricity purchased from the utility or it may be sold to the utility as a supply-side resource.

subsectors:
A classification of customers within a sector by common features. Residential subsectors are by type of home (single-family, duplex, apartment, etc.). Commercial subsectors are generally by type of commercial service (office, retail, warehouse, etc.). Industrial subsectors are by product type (pulp and paper, solid wood products, chemicals, etc.).

tariff:
The rate and the terms and conditions of sale for electric power and energy between utility and customer. It includes the type of service, delivery point(s), limitations of obligations to serve, minimum charges, etc.

technical efficiency:
The efficiency of a system, process or device in achieving a certain purpose, measured in terms of the physical inputs required to produce a given output.

total resource cost:
The total economic cost of acquiring energy resources. For DSM programs, this includes costs incurred by the utility (DSM program administration, taxes and incentives) and by the customer (the cost of the DSM measure net of incentives).

utility cost:
The total financial cost incurred by the utility to acquire energy resources. For DSM, the costs include all utility program costs, including incentive costs.

watt:
The basic unit of measurement of electric power.

12. GLOSSARY OF TERMS USED IN BUILDING PROFILES

PROFILE TERM	EXPLANATION
Building Specifications	Defines the thermal characteristics of the building's exterior components.
Roof/wall construction W/m^2 °C	Defines the thermal loss from conductivity; values are expressed as watts per square metre per heating/cooling Celsius degree.
Shading coefficient	
Window to wall ratio	Defines the ratio of window to insulated exterior wall area.
General Lighting	Defines the predominant lighting types that are used within areas of each building where general tasks are commonly conducted e.g., fluorescent lighting in office buildings or school classrooms.
LPD	Lighting power density
Lux	A measure of light level e.g., how bright it is in the space
Inc	Incandescent lighting
CFL	Compact fluorescent lighting
T12ES	T12 fluorescent lamps, Energy Saving reduced wattage
T8 Magnetic	T8 fluorescent lamps with magnetic ballasts
T8 Electronic	T8 fluorescent lamps with electronic ballasts
Architectural Lighting	Defines the predominant lighting types that are used within areas such as corridors, lobbies, foyers etc.
Other Lighting	Can be defined as other indoor lighting such as high bay lighting in schools.
Overall LPD	The total floor weighted LPD that includes general lighting, architectural and other.
Plug Loads EPD	Equipment power density. Defines the estimated load associated with equipment that is "plugged in" the building's 12-V electrical service. Examples include office computers, photocopiers and printers, fridges, coffee makers, water coolers and other.120-V appliance loads.
Ventilation	
CAV	Constant air volume
VAV	Variable air volume
DD	Dual duct
IU	CAV + perimeter induction units
OA	Outside air
Cooling Plant	Defines the mix of cooling plant types found within the stock of buildings to provide air conditioning.
Centrifugal	Standard centrifugal chillers with a full load performance of 0.75 kW/ton
Centri HE	High effciency Centrifugal chillers assumed to have a performance of <0.65 kW/ton
Recip Open	Semi-hermetic reciprocating chillers
DX	Direct expansion cooling equipment that use small tonnage hermetic R-22 compressors
LiBr	Lithium-bromide absorption cooling equipment
Calculated Capacity	Defines the calculated cooling capacity to meet the interior loads. Values are expressed in square feet per ton of cooling plant capacity.
Cooling Plant Auxiliaries	Defines the chilled water and condenser water auxiliaries needed for the required cooling plant size and cooling loads. Values are expressed as watts per square meter or square foot of building floor space per year.